Exploring the Open Source Hardware phenomenon:

Empirical essays on the role of user communities in the creation of innovation, organizations and markets

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A dissertation submitted in satisfaction of the requirements for the degree of Doctor of Philosophy

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April, 2017

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ACKNOWLEDGEMENTS

To the memory of my parents

To my family who where there for me

To my academic advisors Stefan Haefliger (Cass Business School) and Costas Andriopoulos (Cass Business School), for their patience and guidance

To my friends and colleagues for walking on this journey with me

ABSTRACT

Open source is considered an extreme case of the Open Innovation paradigm (OI). It involves the free revealing of information and a collaborative mode of production among members of communities. The increasing number of open source ventures in product types of tangible or physical nature has evidenced the Open Source Hardware (OSHW) phenomenon. It follows open source principles, but unlike software, the physicality of the product requires investment and a manufacturer for the production of the goods. This dissertation comprises three empirical studies that use multiple case study research to investigate three aspects of this phenomenon and its relation with user communities.

Firms initiate user communities or build linkages to existing ones with diverse purposes, e.g. improving efficiency and generating innovation outputs. In the first empirical study, I argue that the relationships between entrepreneurs and user communities are important to co-create a new market. I show that for the market of OSHW products, firm-community interactions helped to forge a sharing identity and differentiate firms and the market, creating awareness and enhancing reputation, which facilitated the perception of value by market audiences and ultimately the acceptance of the market.

Appropriability is central to the commercialization of products, but conflicts with the free revealing of products' designs. The second empirical study aims to shed light on this tension and to answer how the physical nature of open source products determines how firms capture value. The study discusses the impact on the portfolio of protection and appropriation mechanisms, which includes users communities as a complementary asset. In addition, the appropriation strategy is not complete without governance mechanisms that help to manage the complementary asset.

The third empirical study posits questions related to firms' sustainability, how to implement strategies that support the source of ideas outside firms' boundaries and the maintenance of relationships with external actors. Considering new forms of organizing in alternative spaces such as sponsoring/partnering makerspaces to reach out external collaborators. I use the liminality concept as a lens to shed light on how spaces can help to spark creativity and induce innovative behavior. I propose a conceptual framework that explains how firms craft spaces that facilitate their objectives towards OI.

Keywords: open innovation, user communities, open source hardware, market creation, complementary assets, innovation spaces

1. INTRODUCTION

Innovation has a great impact in our society, it is widely accepted that it fosters productivity and has positive effects on economic growth. The OECD (2015) estimates that the investment in Information and Communication Technology capital alone contributed to 0.35 points of the Gross Domestic Product (GDP) growth of several countries between 1995 and 2013 (See Figure 1.6.1). In contrast to invention, innovation involves the commercialization or implementation of the idea. Innovation is usually associated to Research and Development (R&D) conducted by corporations and technology and it is also linked to entrepreneurship. Schumpeter (1911) posits that innovations occur because entrepreneurs need them, thus innovation is driven by entrepreneurs "in the ability to see connections, to spot opportunities and take advantages of them… opening up new markets" and finding new ways of serving existing ones (Tidd and Bessant, 2013, p. 4).

The most common and simple definition of innovation is to create something new. It could have a degree of novelty that refers to whether the innovation is new to the organization, new to the market or new to the world (Edison, et al., 2013). However, the idea of innovation of a serendipitous action in an organizational context is problematic, therefore another view is to see innovation as a process that covers the creation of relevant knowledge for the development and introduction of something new and useful (Wallin and von Krogh, 2010). This allows to have a common understanding of the activities and goals and although the steps can vary depending on sectors, firms and even who the innovator is, it could be possible to organize for it, i.e. it can be managed and consequently get its benefits.

Innovation is necessary for organizations' sustainability, to introduce new services, processes or products, therefore firms need to be alert to external or internal opportunities. For a while the collaboration of firms with partners (including Universities and Governments) or suppliers was central. Alliances and joint ventures were the mechanisms by which firms accessed or completed knowledge necessary for innovation. However, those relationships are based in contracts with tight Intellectual Property (IP) protection, which is a manufacturer-centered view of innovation. There are other ways of doing innovation, developed by distributed volunteers or users, with no contractual commitments, which are part of the Open Innovation (OI) paradigm, explained next.

1.1. The Open Innovation paradigm

The Open Innovation (OI) paradigm assumes that established firms with a tight appropriability regime collaborate with external actors in order to increase flows of knowledge, improve internal innovation and expand markets (Chesbrough, 2003). This view has been expanded, since openness happens across several dimensions, depending on the directionality of innovation flows: inbound (acquiring and sourcing) and outbound (selling and revealing) and it is subject to pecuniary and non-pecuniary interactions (Dahlander and Gann, 2010). This broader view includes the user innovation (von Hippel, 2005) and open source streams of research in which openness not only indicates collaborating with external actors, but also it is understood in terms of free revealing of information (West, Salter, Vanhaverbeke, & Chesbrough, 2014).

Innovation coming from outside firm's boundaries offers benefits such as the minimization of development cost (West and Gallagher, 2006a) through the accessibility of diverse resources, the creation of network effects for the diffusion of the innovation (von Hippel and von Krogh, 2003; West, 2003). The implementation of OI practices has consequences for the management of innovation. Firms have to find the best ways to manage the knowledge flows and trade them (Tidd and Bessant, 2013) and look at the cost-benefits. Since open strategies might not be always superior to the closed counterparts and firms often incur in substantial costs when using external search strategies across multiple domains (Laursen and Salter, 2006).

The firm-centric and the peer or community innovation require different logics for organizing and firms need to be prepare to cope with the complexity of creating value in the continuous development of product and services through accessing knowledge external to the firm (Lakhani, Lifshitz-Assaf, & Tushman, 2012). In terms of free revealing, Open Source Software (OSS) born as an alternative model of software production, a private-collective model by which the software developers' communities get private benefits consisting of reputational advantages and reciprocal exchange patterns that motivates them to produce a public good and deliver innovations (Harhoff and Mayrhofer, 2010; von Hippel and von Krogh 2003, 2006). OSS has had an important impact, changing the industry landscape with Apache - web server software, Firefox browser competing with proprietary software from Microsoft, MongoDB and Cassandra taking on legacy Oracle databases, OpenStack and Docker threatening virtualization giant VMware and Linux displacing Solaris and Windows Server software.

Additionally, openness became a relevant purchasing criterion and an element of competition since it allows firms to compete based on differentiation (Henkel, Schöberl, & Alexy, 2014). However, open source research's applicability to industries outside software has been limited (Raasch, Herstatt, & Balka, 2009a) despite it can have a high impact on our society, an evidence is how Tesla recently opened all its patents for the advancement of electric vehicle technology (Tesla, 2014) with the expectation to accelerate the development and diffusion of the technology. Another point is that OSS and user innovation (von Hippel, 1986) are two areas that highlight the increasing importance of the relationship between firms and user communities, very much in evidence across a diverse number of businesses today. With the help of user and developers communities, entrepreneurs have created new ventures for the commercialization of OSS products (West and Lakhani, 2008).

1.2. The Emergence of Open Source Hardware (OSHW)

The historical precedents that influenced and shaped open source include the Homebrew Computer Club and the Amateur Radio community. They started the knowledge-sharing practices and the hacking traditions, when hacking was conceived with more positive connotations and computers were sold in kits with schematic diagrams included (OSHWA, 2013). The hacker ethos is characterized by curiosity, limited trust in authority and the belief that the creation of things is possible by joining forces, and that there is value in solving technical challenges that gives internal self-fulfillment, truth, independence, and autonomy (Himanen, 2001; O'Mahony, 2005).

Open Source Hardware (OSHW) shares with OSS the underlying values and practices, "shared rights to use the resulting technology as well as the collaborative development of the technology" (West and Gallagher, 2006b, pp. 322). They also face similar challenges such as the management of Intellectual Property (IP) for the protection to commercialize products (Laursen and Salter, 2006, 2014), the management of a community (O'Mahony and Lakhani, 2011). In other words, open source should deal with the organization of practices regarding governance, membership, ownership, and control over production (O'Mahony, 2008). The OSHW phenomenon (Raasch et al., 2009a) is often taken as equivalent of open design, but in open design users design the final product, rather than a private company (Vallance, Kiani, & Nayfeh, 2001), whereas in OSHW the products can be designed and sold by single firms.

Thus, there is a tension originated by the fact that the product information is 'free' available to anybody vs. the need for creating revenues. However, unlike OSS, the collaboration model in OSHW: 1) investment is required for prototyping, 2) the share of components is problematic and 3) the availability of mature software tools for collaboration is sparse (Mellis and Buechley, 2012). In spite of its early stage and the second wave started in electronics, OSHW has expanded to a wider spectrum of industries like vehicles (Local Motors, TABBY EVO), telecommunication (Phonebloks, OpenMoko), 3D printer (RepRap), medical devices, etc.

Several initiatives around OSHW emerged in the late 1990s and disappeared within a year or two, for instance Open Design Circuits by Reinoud Lamberts. Nevertheless, by the mid-2000s, some factors contributed to the resurgence of OSHW projects. One is the widespread availability of the Internet, which provided the way for sharing designs and documentation. Other factors are the commercial success of OSS and the possibility to acquire production tools at low cost. I argue that the communities (users/developers/makers) also influenced in the success of the market in the first paper (Chapter 2). More initiatives appeared over the time, like the Tucson Amateur Packet Radio (TAPR) or the European Organization for Nuclear Research (CERN) Open Hardware License, but it was not until 2010 that OSHW entrepreneurs united effort to establish a standard definition and founded the OSHW Association and in 2014 the association received its nonprofit status (OSHWA, 2013). Now OSHW is growing, there were around 100 OSHW startups in 2013 (Berchon, 2013).

My background in Information Technology drove me to explore and study this contemporary phenomenon, besides scholars proposed that open source innovation can be developed further as a phenomenon-based research (Lee, Raasch, Herstatt, & Spaeth, 2011). OSHW is a phenomenon that is important for the management practice and for theoretical development as it can challenge current theories (Von Krogh, Rossi_Lamastra, & Haefliger, 2012). Therefore this dissertation follows a phenomenon-driven approach, i.e. it has an "emphasis on identifying, capturing, documenting, and conceptualizing a phenomenon of interest in order to facilitate knowledge creation and advancement. It focuses on contributing to knowledge within a field rather than to specific theory" (Schwarz and Stensaker, 2014, p. 480). I saw the emergence of OSHW as an opportunity to add knowledge to the OI field.

1.3. The Microcontroller Industry

OSHW first became popular in the electronics industry with Arduino, which was the first large-scale success in OSHW (Gibb, 2014). The startups that appeared at the beginning of the 2000's were specifically producing and selling microcontrollers. Microcontrollers, also known as single board computers, are currently a $3.5bn market and continue growing (Harrop, 2016). In the 70's, Intel to create the 4004 first single chip of 4 bits Busicon for a Japanese calculators company. Busicon held exclusive rights but eventually granted permission to Intel to sell the chip. Later on, ex-employees of Intel designed and commercialized new models. All those early chips were very expensive, until 1975 when Motorola engineers left for MOS Technology and created the 6502, an 8-bit microprocessor; the price dropped down to one-sixth the cost of competing designs and sparked other projects and the home computer revolution of the early 1980s (Faggin, 1992; Miller, 2014).

For an additional cost to the original price, the chips were sold with a documentation package and users made copies of the documents, as it was cheaper to distribute product information. In 1975 PIC's microcontroller from Microchip Technology became the backbone of the hobbyist market (factors: low cost, ready availability and proliferation of free programming tools). Other companies were Picaxe chips, which are development boards used for education. A starter kit was designed and preprogrammed with firmware to understand BASIC or graphical flowchart languages, to allow experimentation and prototyping and teaching. Similar boards like Parallax BASIC stamp board were patented and not affordable (Keisch, 2014).

Corporations like Intel, Atmel, Texas Instruments or FreeScale Semiconductor a spun off of Motorola have the patents of many high performance microprocessors. The next wave of microcontroller's innovation goes to open source to address the needs of a niche market. New entrants created open source microcontroller boards and a new market, they have caught the interest of many and even firms such as Intel are joining the trend. Given that the resurgence of OSHW happened in the microcontroller industry, I chose to study some of the startups that appeared during this new wave, the case studies are described in section 1.5. OSHW re-appeared with the sharing and learning practices in digital formats that ventures are using to commercialize products. The startups sell open components, breakout boards and electronic kits and there has been progress in open source tools, for example, laser cutters, jigsaws, and 3D printers (Gibb, 2014).

1.4. Research Questions

The dissertation consists of three essays, three empirical studies that focus on the entrepreneurial, strategic and innovation aspects of the OSHW phenomenon. Each empirical study is presented as a chapter with the aim to act as standalone research paper for submission to an academic journal. All the essays contribute to clarify the viability of the existence of OSHW organizations and their engagement with user communities. Each paper can be read and understood independently and answer unresolved questions related to the phenomenon.

The first essay explores how the entrepreneurial and the collective action of user communities contribute to the creation of markets. The entrepreneurship literature focuses on the entrepreneur dealing with the new market situations of uncertainty and ambiguity whereas the open innovation literature stresses the work of users/user communities that support the creation of products/markets. I propose in Chapter 2: Building user communities and the co-creation of a market, a framework to address the following research question: How do entrepreneurs and communities' actions converge towards the creation of a market? I propose a framework based on firm-user community interactions to explain the co-creation of value that makes possible the emergence of innovations, firms, and markets. This aligns with a systemic view of markets, in which entrepreneurs and other stakeholders with pecuniary and non-pecuniary interests join actions

In addition to the creation of value and the market, firms increasingly engage in open collaboration and follow a selective revealing strategy (Henkel, 2006), which allows sourcing external ideas for innovation and appropriate value. However, open source lack of tight IP mechanisms (patents) conflicts with the appropriation of value and it is through a combination of methods that firms appropriate returns (Dahlander, 2005). Among them, complementary assets play a critical role and open source/users communities do activities that fit that role (Dahlander and Wallin, 2006). In Chapter 3: On appropriability strategies for Open Source Hardware, my aim is to address these issues and answer the research questions: How does the physical nature of open source products determine how firms capture value? How and when do firms use communities as a mechanism to appropriate value? The findings show that the tangible nature of the open source products impacts the composition of options. Besides presenting the portfolio of appropriation methods and governance mechanisms, the study supports the view of communities as complementary assets.

Furthermore, the way to innovate and search for new ideas has been transformed as firms collaborate with external actors. The interaction and development of relationships with externals are important for new product creation and sustainability. Firms are creating places that can fulfill objectives towards open collaboration, making interactions with external actors possible. The interstitial and liminal spaces are types of spaces that induce behavior such as creativity (Howard-Grenville, Golden-Biddle, Irwin, & Mao, 2011) and can help firms to achieve change. I borrow those concepts to discuss liminal spatial dimensions that support innovative behavior in Chapter 4: Crafting physical spaces in open innovation environments. The research questions are: How do firms establish physical spaces that facilitate the implementation of open innovation objectives? How do spaces contribute to experiences that affect innovation and collaboration?

1.5. Case Studies Overview

The three papers follow an inductive methodological approach with a case study design (Eisenhardt, 1989). I use multiple-case studies (Eisenhardt and Graebner, 2007) for identifying and analyzing patterns. This section presents an overview of the case studies, which comprise three startups and one non-profit organization. In Chapter 4, the cases correspond to innovation spaces owned/sponsored by three of the firms studied in the first chapters. Details about the methodologies can be found in each paper method section.

Case 1. Arduino

Arduino is a limited liability company (LLC) that sells an open source electronic prototyping platform comprised by electronic boards and software. It was founded in 2005 by academics with engineering background, working in an educational institution for interaction designers in Italy. Although it is a for profit organization, its mission has a strong orientation towards education, besides the firm has received an honorary mention in the Digital Communities section of the 2006 Ars Electronica Prix, and recently has been recognized as one of the digital innovations for social change.

Arduino was open from its origins, i.e. the hardware designs and software used in the products are available to the public domain, so that anyone can access and use that information without paying anything. Based on different open source tools available at the time and inspired in Wiring board that uses Processing, an Integrated Development Environment (IDE), the founders improved and created a new board and a new IDE portable

to Linux, Mac OS, and Windows. With headquarters in Boston and Switzerland, the official Arduino boards were manufactured by SmartProjects in Italy and by SparkFun Electronics and Gravitech in USA. The firms was very proud of the manufacturing in Italy and used as marketing tool, a dispute among founders changed the production sources including a Chinese manufacturer and initiated a legal battle for the brand (name).

Apart from having offices around the world (Italy, India, USA), the firm uses a multilingual forum, Google+, a developers mailing list, GitHub, blog, Wiki, and social media tools such as Twitter, Flickr, and delicious to communicate and collaborate with its community. The company sold almost 300,000 units in its first seven years, and has spawned dozens of derivative products (Igoe and Mota, 2011).

Case 2. BeagleBoard

BeagleBoard.org foundation is a US-based 501(c) non-profit organization, founded in 2008 with the support of Digi-Key. Its founders, former employees of Texas Instruments (TI), continue to work with the company while providing support and development of the BeagleBoard.org project. On-going funding for board prototypes has been provided by CircuitCo Printed Circuit Board Solutions US-based, which is the primary manufacturer of the products. CircuitCo pays volume prices for the TI and all other components.

Despite the foundation does not currently receive any money for board sales, and its mission as stated in its website is 'BeagleBoard.org seeks to foster the advancement of open source hardware and software for building embedded computing solutions at all skill levels', the revenues on board sales are in excess of $1 million annually (Igoe and Mota, 2011). The Foundation has a Board, which initially was composed by the founders and employees of TI. Now the members of the Board are one from a University, two manufacturers and one of the founders.

The boards use technology of TI in terms of hardware and for the software originally worked with Linux, but has expanded to Ubuntu, QNX, Windows Embedded, Android and web tools to bare metal and even Arduino/Wiring-style programming. It does not take responsibility to manage projects originated by its community. However, the organization website holds live chat, forums, blog and allows registering their project and information about the licenses and status of the projects. BeagleBoard also participates in all the events organized for the maker community like Maker Fairs and OSHW summit.

Case 3. SparkFun Electronics

Founded in Colorado, USA in 2003 by an engineer, SparkFun is an online retail store that sells the pieces to make projects with electronics. In addition to products, SparkFun offers classes and online tutorials designed to help educate individuals in embedded electronics. The company's self-stated aim is to educate people about electronics and support open source. SparkFun has become a supplier for various devices including Arduino. SparkFun's spin-off a service company called BatchPCB to explore new businesses and as a way of giving hobbyists, students and engineers access to small runs of custom PCBs fabricated for a reasonable price. It was sold in 2013 to OSH Park.

SparkFun is a for-profit entity with USD $75 million in sales, USD $30 million in revenue (2013), currently employs 151 employees and holds over 3,500 components and widgets in the product catalog from other manufacturers. SparkFun manufactures and sells kits and complete products and has around 450 active open source designs and many tutorials posted in the website. The company maintains a direct contact with customers and the community through the website's forums, comments, Internet Relay Chat (IRC), Facebook, Flickr, Twitter, Google+, YouTube, and Vimeo.

Awards for SparkFun relate to its performance and working environment. SparkFun has been recognized as one of the top places to work in the Denver Area (Denver Business Journal), for increasing the amount of jobs in the community, Mercury 100's fastest growing companies in Boulder and as a non-traditional office place (Forbes Magazine).

Case 4. Seeed Studio

Seeed Studio was founded in July 2008 by two engineers, it has headquarters in Shenzhen, China and has opened offices in San Francisco in 2015 to be closer to customers in USA and in Taiwan. It started improving the Arduino and SparkFun boards and selling their own versions. Now it provides more pre-made middleware and services around consumer electronic products. The mission of Seeed is "to fuel ubiquitous electronic innovation with fast prototyping modules, development platform and customizable solutions" (Seeed Studio blog). To help makers transform their ideas into actual products. The services offered cover three main aspects: selling open hardware components/modules, providing prototyping-to-production services and sponsoring activities.

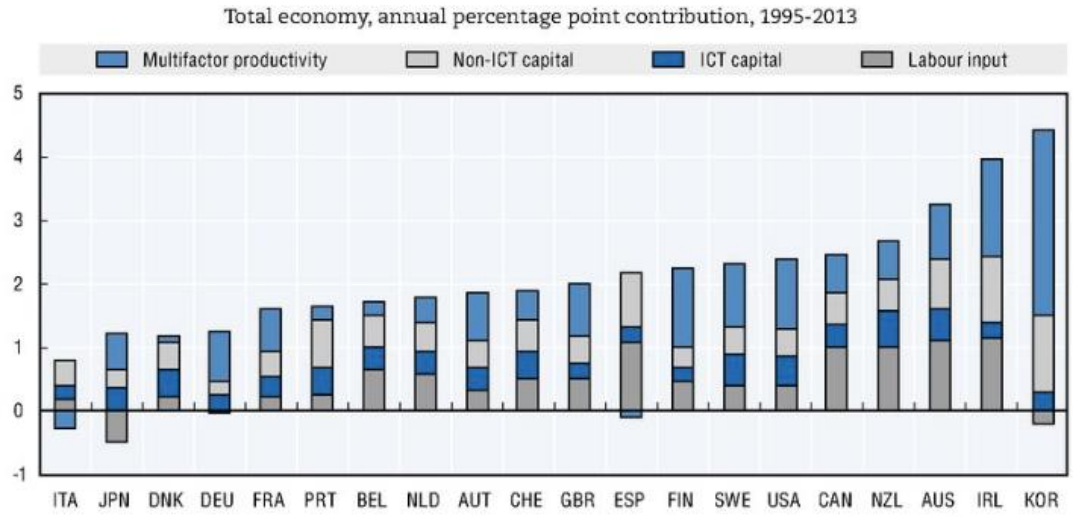
Seeed Studio with USD$50 million in sales and about 40-50% profits in 2015 (SIDA, 2015)

employs 210 people and has customers from USA, Europe and Japan; some of them are top 500 companies. It has more than 300 distributors serving more than 100,000 makers in around 200 countries. Although Seeed makes OSHW products and prototypes, it sells proprietary products from other manufactures as well. The firm started to support the Shenzhen Mini Maker Faire and then it became the partner, now is the organizer of a full Maker Faire. Similar to other OSHW firms, Seeed's forum, blog social media, Twitter, Google+, etc. are tools used to attend the community.

The firm has received an honorary mention in the Digital Communities section of the 2013 Ars Electronica Prix and the recognition and support of the Chinese government. In addition, Seeed founded one of the first makerspaces in China (Chaihuo) and collaborates with a hardware accelerator (HAX accelerator, formerly HAXLR8R) to support hardware startups from around the world.

1.6. Figures

Figure 1.6.1 Contributions of Innovation to GDP growth



Source: OECD (2015a), *OECD Compendium of Productivity Indicators 2015*, OECD Publishing, Paris, *http://dx.doi.org/10.1787/pdtvy-2015-en*.

2. BUILDING USER COMMUNITIES AND THE CO-CREATION OF A MARKET

Abstract

User communities are becoming part of the organizational life cycle and are helping entrepreneurial ventures enter new markets. This study aims to shed light on how entrepreneurs and communities converge in the process by which firms and a market emerge. The market for products based on Open Source Hardware (OSHW) provides the context for this inductive, longitudinal, multi-case study research. The findings suggest that once entrepreneurs create/join a community, both firm and user community co-develop together and their actions clarify the products and capture market audiences. The study adds to the understanding of the construction of new markets by providing a framework that explains how entrepreneurs and user community engage in constant interactions that help to co-create an identity, enhance reputation and get information advantages by sourcing user knowledge. The repertoire of firm-community interactions contributes to generate a common perception of value for the product, firm and market, by market audiences, leading to the acceptance of the market.

***Key words**: Nascent markets, user communities, open source hardware, co-creation*

2.1. Introduction

The creation of new markets is important for economic and human welfare and has been associated to entrepreneurship and innovation (Schumpeter, 1950, 1911). Market-creating innovations transform products and services that were not accessible to mass population. At the same time, the changes to the products require building new supply networks and distribution channels. By fulfilling these new needs, the innovations support jobs' creation, growth and prosperity, e.g. the model T-Ford and the Personal Computer were made affordable to new populations of customers (Mezue, Christensen, & van Bever, 2015).

Although diverse aspects concerned with the understanding of how markets come into existence have been uncovered in the entrepreneurship literature, such as the formation of an identity to gain legitimization (Navis and Glynn, 2010), the construction of boundaries (Santos and Eisenhardt, 2009) and the creation of value (Khaire, 2014), the creation of markets is a long process that requires putting together a lot of pieces and is full of

incomplete information (Sarasvathy and Dew, 2005) and more research is necessary to get a better understanding of how industries emerge (Forbes and Kirsch, 2011). The term industry is often considered as synonym of market, which I use indistinctly here.

Entrepreneurs face risky and uncertain environment in early stages of markets and aspects such as agency, incentives and motivation of actors at micro, macro and meso levels differ. The micro level is marked by entrepreneurs' activities, to get on board people or institutions that help in their aims. There are two logics that entrepreneurs might follow in venture creation: effectuation and causation (Sarasvathy and Dew, 2005; Santos and Eisenhardt, 2009). At a macro level, the efforts of groups of people, inspired in social movements and motivated by a common goal that appeals to emotions, create markets such as the automobile (Rao, 2009), craft brewery (Carroll and Swaminathan, 2000) and artisanal wine (Lukacs, 2000; O'Mahony and Lakhani, 2011).

At the meso-level the collective action of external communities is present in the creation of markets. For instance communities of financial security analysts and market investors were gatekeepers for the legitimization and assessors of the satellite radio industry (Navis and Glynn, 2010) and user communities have assisted user entrepreneurs in the opportunity identification period in the development of sport equipment (Shah and Tripsas, 2007). In addition, various actors (e.g. media, educational institutions, etc.) can create value in various ways, influencing how markets come into being (Khaire, 2014). Yet in this systemic view customers/users have been a particular kind of stakeholder with a passive role: receivers of the value.

However, user communities have been partners of firms in the co-creation of value, participating in the development of products and services (Prahalad and Ramaswamy, 2004) and in the selection for production of items (Lakhani and Kanji, 2008) and in software development with Open Source Software (OSS) ventures (Dahlander and Magnusson, 2008). Yet further research is necessary to understand the implications of applying firm-communities relationships strategies on industries life cycle, i.e. the rise and death of market niches (Fosfuri, Giarratana and Roca, 2011) and to solve questions regarding the basis of firm-community relationships, the types of community actions that lead to market creation and how firms and communities influence each other (O'Mahony and Lakhani, 2011). Therefore, I investigate the interplay between firm and community in the process of creating

a market by posing the following research question: *How do entrepreneurs and user communities' actions converge towards the creation of a market?*

The emergence of firms and a market of products with open designs free revealed to the public, known as Open Source Hardware (OSHW), are the settings of the study. Open source products of tangible objects is a niche that is spreading to several industries, e.g. electronics and automotive (Raasch, Herstatt and Balka, 2009a). This study follows a producer-centered approach, rather than firms collaborating with an independent community (Dahalander, 2007; O'Mahony, 2003, 2007; West and O'Mahony, 2008).

The contribution to the market creation and user community literatures is two-fold. First, it adds to the understanding of the emergence of new ventures and markets in open source (Dahlander, 2007) by providing a framework, with new entrants and user communities as the focal actors, that explains how with a repertoire of firm-community interactions (identity, reputation and knowledge sourcing) those actors contributed to the creation of value that lead to the emergence of the market. Presenting user communities as an active participant of this process yields new insights into the social construction of market perspective taken by other researchers (Khaire, 2014; Navis and Glynn, 2011).

Second, the study extends current knowledge on firm-community relationships (Dahlander, 2007; Dahlander and Magnusson, 2008; O'Mahony and Lakhani, 2011) by attending closely to how sponsored communities and firms interact and affect core organizational processes beyond the co-creation activities in product development (Prahalad and Ramaswamy) It shows how new entrants exploit other attributes of community, e.g. co-creation of an identity (Fosfuri et al., 2011) and co-development of a reputation that influence the chances of survival (Rao, 1994). Implications for practitioners reside in the creation and maintenance of sponsored communities, incentives and resources for the community in early stages.

Next, I present the theoretical background and in section 2.3, I describe the methods and sample. In section 2.4, I present the findings by outlining the process by which entrepreneurs and the community contribute to the emergence of the market. Section 2.5 contains the framework for market creation and implications for theory are discussed in section 2.6. Finally, the conclusion with the limitations of the study and suggestions for future research are listed in section 2.7.

2.2. Theoretical Background

I draw upon entrepreneurship and open innovation literatures regarding market creation, OSS and user communities' research to investigate how entrepreneurial and community actions converge in the process of how markets come into being. I use indistinctly the terms market and industry as the literature often does it and I focus on the earliest stage of development comprised only by startups. A market, from a product/firm view, derived from industrial economics is defined as "a group of firms producing products that are close substitutes for one another" (Forbes and Kirsch, 2011; Porter, 1980). Entrepreneurship scholars, who use institutional theory, see new markets as new categories with lack of identities and boundaries (Khaire, 2014; Navis & Glynn, 2010). The category represents the market as an economic space and requires going through a legitimization process involving identity formation influenced by public announcements and the media (Ozcan and Santos, 2015). It is also conceptualized as a "forum of conversation and interaction between consumers, consumer communities and firms" (Prahalad and Ramaswamy, 2004).

Like the market definition, prior research on the creation of market uses different theoretical lenses. Among them, the resource mobilization theory suggests it is a political process (Rao, 2004), institutional entrepreneurship and resource dependence theory propose it as a set of processes and multiple mechanisms that "generate cognitive (identity-based), relational (alliance-focused), and resource (acquisition driven) structures for firm boundaries and nascent markets" (Santos and Eisenhardt, 2009, p. 645). Scholars using institutional theory expose its social construction, such as sensegiving and sense making dynamics (Navis and Glynn, 2010) or see the market as a result of value creation processes of individuals and shared social interactions that enable market audiences to make sense of the market (Khaire, 2014). On the other hand, there is an increasing interest on firm-communities interactions and their potential for value creation (Fosfuri, et al., 2011; Prahalad and Ramaswamy, 2004) but do not address the market creation process.

In the open innovation literature, scholars begun to study different types of firm-community interactions and market creation strategies that firms can follow with communities (Dahlander, 2007; Dahlander and Wallin, 2006; Dahlander and Magnusson, 2008; O'Mahony and Lakhani, 2011; Shah and Tripsas, 2007). Although useful, those studies take the existence of communities as a given or focus on differences between autonomous and sponsored communities leaving the social aspect of market construction unexplored. This study focuses on new entrants sponsoring communities and their interactions in early stages

of a market. To base my arguments, instead of focusing on one restrictive theoretical lens, I organized prior research into three perspectives to identify attributes important for firm-community relationships and what entails a social construction of market with the following dimensions: the focal actor (agency), goals, the time frame to achieve goals (long vs. short term), the incentives of the participants, the effect on the emergent market and the strategies or mechanisms used by the actor to achieve their goal.

2.2.1. Entrepreneurial action in the creation of markets

The entrepreneurial perspective focuses on the entrepreneur's ability to influence the behavior of others in ways that produce outcomes. The goal of the entrepreneur for the creation of products and markets comes either from an opportunity discovery as stated in causal theories. Whereas in effectual theories the goal being defined depends on the entrepreneur's circumstances. Other actors will help entrepreneurs to overcome limitations to create and dominate a new market, for example to get access to and to control and even to take possession of critical resources.

During the period before new industries become understood and taken for granted, the environment presents high ambiguity, which is the "lack of clarity about the meaning and implications of particular events or situations" (Santos and Eisenhardt, 2009, p. 644), and uncertainty. Uncertainty refers to the lack of patterns in the structure-environment (Davis, Eisenhardt, & Bingham, 2009) and when the probability of outcomes cannot be predicted. The actions of the entrepreneur secure results she/he desires by using different strategies and tactics. The strategies involve mechanisms with cognitive and social properties connected, used to clarify firm's identity and facilitate understanding of new firm/market to win acceptance or gain legitimization.

Entrepreneurs gain influence over others who have the resources, knowledge and means, using templates, story dissemination and soft-power strategies like illusion in the form of signaling leadership, exploitation of the tendency of others, timing and alliances and acquisitions to dominate the market (Santos and Eisenhardt, 2009). Other mechanisms are product differentiation and patents (Giarratana, 2004), entrepreneurs' experience acquired in prior industry affiliations (Benner and Tripsas, 2012), the use of vocabulary recombination to describe the product or firm (Grodal, Gotsopoulos, & Suarez, 2015) and symbolic management, when using labeling in the name of the firm to be associated with certain markets (Granqvist, Grodal, & Woolley, 2013).

However, positivistic assumptions about a world with stable states within which human action occurs is hard, entrepreneurs cannot always predict how the development of their ideas will do at early stages of markets. Not only potential customers have questions regarding what the product and the firm is about, but also entrepreneurs do not have for certain who will buy their products or who will produce them, etc. Thus, an effectuation logic than explains entrepreneurial action in the creation of any type of venture (profit, non-profit, social, and hybrid) under high levels of ambiguity and uncertainty seems suitable (Read, Sarasvathy, Dew, & Wiltbank, 2016). Instead of a specific goal, entrepreneurs start with an important self-awareness of who I am, what I know and whom I know, in other words, the categories of means: their identity, their knowledge base, and their social network (Sarasvathy, 2001).

Based on the effectuation logic, Sarasvathy and Dew (2005) explain market creation as a transformation process involving a network of stakeholders. Then entrepreneurs persuade persons or organizations to become part of an effectual network. The members of the network enable but also constraint what/how issues around the product are going to be and therefore negotiate about aspects of the future market. The motivations in being part of the effectual network varies, there is a wide range of reasons such as pre-existent preferences, docility, passions, convictions, self-interest, fun and even indifference, but individuals commit to the extent to which parties reach a point where they are comfortable to sacrifice certain interests in the negotiations. At any point of time, entrepreneurs focus on controllable aspects within their possibilities and their stakeholders, to co-create rather than predict the uncertain future (Sarasvathy and Dew, 2005).

In effectuation and causal theories, the entrepreneur is the economic agent, the driving force behind shaping how users and in general other constituents understand the firm and the market. Although they recognize interdependences with other actors, it is difficult to see how other organizational forms such as user communities fit in them. Communities or network like organizational forms differ from market and hierarchies (West and Lakhani, 2008) therefore market mechanisms and usual incentives might be inadequate to address the interrelation with communities.

2.2.2. Collective action's influence in the formation of markets

Moving to the second perspective, in which the collective action of groups of individuals makes the emergence of markets possible. This view has its roots on the resource

mobilization theory (McCarthy and Zald 1973) a core in social movement studies, in which the common goal shared by the group allows the mobilization of resources and the emergence of a collective identity. Polletta and Jasper (2001) define collective identity as "an individual's cognitive, moral, and emotional connections with a broader community, category, practice, or institution".

In contrast to the entrepreneurial view, the collective action view relies on elements such as a common interest, non-pecuniary benefits and emotional cues that create the favorable conditions for the establishment of new markets. The automobile industry is an example that illustrates how a group of automobile enthusiasts lobbied governments to create laws and roads and promoted races that gave the perception of security to audiences. Activists and volunteers worked together to produce a change in the status quo and to express a new identity. With a common goal and the activation of emotions that mobilized resources, the automobile market took off (Rao, 2009).

Other examples are how the craft-beer market comes into being despite the dominance of industrial beers thanks to the cultural and social mobilization of groups of people, who distinguish the production method and goods from mass-market competitors (Carroll and Swaminathan, 2000). And the market of artisanal wines, when the founder focused on growing a community and provided barrels required for winery production, enabling the founding of new ventures, all aimed towards the creation of the market (Lukacs, 2000; O'Mahony and Lakhani, 2011).

Those examples speak to the collective action defined as an action system in social movements, the mobilization of groups and organizations to achieve social change, e.g. launching a public campaign to support a cause (Gurses and Ozcan, 2015). To explain the mobilization of resources at a community level, I start with the definition of 'communities', which O'Mahony and Lakhani (2011) define as "voluntary collections of actors whose interests overlap and whose actions are partially influenced by this perception" and who do not necessarily share a geography. Communities are seen as the link of individuals to organizations and also to the market as they organize for collective outcomes (von Hippel and von Krogh, 2003; von Krogh, Spaeth, & Lakhani, 2003) and facilitate the genesis of new organizations and markets (O'Mahony and Lakhani, 2011).

The broader definition of communities cover nuances among these non-formal organizational forms, for example OSS developers community differs from von Hippel's

(1988) ‘user community’ definition, which considers that user-innovators do not work with each other but provide their innovations to the firm, therefore it “is merely the sum—and not the combination—of each component’s idiosyncratic behavior” that makes the innovation possible (Rullani and Haefliger, 2013, p. 946). Users, open source developers or innovation communities are outside the boundaries of organizations, contrary to communities of practice that are built within large organizations (Wenger and Snyder, 2000).

These differences influence how entrepreneurs approach communities. The term ‘user entrepreneurship’ refers to entrepreneurs, who usually are users or come from user communities and share their work to benefit from the collaboration and improvements by other users. Information sharing generates interest in the product and contributes to the fortuitous creation of firms and markets (Shah and Tripsas, 2007), for instance new products in extreme sports (Shah, 2005). These activities trigger collective actions useful for the identification of opportunities, the testing and experimentation of an idea, the improvement of the product and the generation of interest, which allow the creation of the new market (Shah and Tripsas, 2012). Therefore users and user communities’ innovations (von Hippel, 2005) have been seen as possible mechanisms of industry emergence (Shah, 2007).

By contrast founders of software ventures, who collaborate with OSS communities, have an intention, they try to identify and occupy a niche where they could be the dominant player and work proactively to shape their niche in the market. Firms establish new communities and work with them to develop something unique and the community serves as a marketing tool to increase brand recognition. The large number of participants in communities generates high level of awareness, useful to expand the niche (Dahlander and Magnusson, 2008).

Among the advantages that OSS communities can provide are the mitigations of liabilities of newness and smallness, by functioning as a marketing channel that gives visibility to new firms, facilitate development and support recruitment (Gruber and Henkel, 2006). But these benefits are limited due to the different values both entities hold (Dahlander and Wallin, 2006; Dahlander and Magnusson, 2008). The challenges of working with external actors such as communities are the loss of knowledge and intellectual property (Henkel 2006; von Hippel and von Krogh, 2003). Furthermore, firms might do not know how to motivate people to join their projects; as a result many new online communities fail to

flourish. Carving out a niche, defending it and getting critical mass is far from easy, people do not join automatically, only about 10% of the thousands of open source projects on SourceForge in 2008 have more than three members (Resnick, Konstan, Chen, & Kraut, 2011).

A drawback of the collective action view is that open source developers communities have broad and ambiguous goals, which do not fit with the explanations that resource mobilization theory offers. Thus, to drive the collaboration of participants requires more instrumental motivations such as reputation, learning opportunities and control over technology known as communal resources (Spaeth, Haefliger, & von Krogh, 2008).

2.2.3. A co-creation approach for nascent markets (Systemic perspective)

A third view on the emergence of markets is that entrepreneurs are part of a network, which includes other constituents (e.g. media, suppliers, etc.) contributing in different ways to the construction of value and ultimately to the creation of the market. This holistic approach, a systemic view of the creation of market, emphasizes the social construction of the market with the presence of stakeholders that have different interests and which actions build up a collective sense-giving/sense-making of the market. Entrepreneurs frame and develop ties while other actors generate awareness, assess and evaluate the qualities of the good. All those activities delineate the market and create a shared perception of worth. The incentives for the actors lay on the potential economic opportunities and it is the aggregate effort of each of them that increases the favorable perceptions of the new market and firms within it e.g. Indian high-end fashion industry (Khaire, 2014).

New markets encompass diverse entities with/without a direct economic stake in the sales of the products. The range of actors relevant to industry emergence comprises those producer firms whose goods and services define the industry, buyers and suppliers as well as providers of critical resource endowments, such as universities that may represent a source of human capital or investors that help to finance the industry. A third group of actors includes public sector institutions, such as patent agencies or other government ministries devoted to cultivating industrial development, as well as non-profit institutions, e.g. trade associations and standard-setting bodies (Van de Ven and Garud, 1989). Entrepreneurs and diverse stakeholders work together towards gaining customers' preference in the new market.

The creation of value is paramount to the market creation so various actors can get benefits. The value as well as the structural dimensions are important for legitimization. In some markets it is necessary the collaboration of prominent firms and organizations that allocate resources and define technologies in a new way to organize economic activities (Ozcan and Santos, 2015). Yet those studies portray customers/users as passive recipients of the creation of value, which is a very limited role. That view on value and value creation has been challenged by the notion of co-creation of value with customers in the development of products (Prahalad and Ramaswamy, 2004), though the firms that have applied a co-creation strategy are established firms, some of the principles are similar to the open source collaboration (e.g. transparency, access and dialogue).

Users not only receive the value created in the form of the actual product but also sometimes royalties and can participate in the co-creation of services (e.g. DHL) and in marketing activities like producing video advertisements for products, which is more user generated content (e.g. Fritolay, gopro). Firm-user interactions are happening in platforms of engagements, which are seen as the locus of value creation (O'Mahony and Lakhani, 2011; Ramaswamy and Ozcan, 2014). This suggests other ways to co-create value with user communities for markets audiences (i.e., media, suppliers, customers, etc.) as firms are increasingly interacting with social groups or target communities.

Other examples are software ventures associated with OSS communities that worked along financial investors and the media to generate public interest and develop a niche (Dahlander, 2007; Dahlander and Magnusson, 2005). And Threadless' founders seized the opportunity of the relatively untapped t-shirt niche market, working with their community (Lakhani and Kanji, 2008). Furthermore, when firms share and are congruent with the values of the community, both can co-create an identity. An identity-enhancing relationship triggers a strong reciprocity that firms can employ to co-develop products. And the products can become a symbol, a manifestation of community values and reinforce loyalty and commitments. Strategic interactions such as those that enhance identity are difficult to imitate because unfold across time and are idiosyncratic (Fosfuri et al., 2011).

Summing up, working with a user community demands an understanding of how entrepreneurs reconcile the different goals and learn to mobilize resources with non-pecuniary goals towards the creation of value. It is important to investigate how both interests and actions towards the value of the market converge and to investigate the

interrelation of entrepreneurial activity and user community' actions that unfold in the early stages of market creation (O'Mahony and Lakhani, 2011). A summary of the three perspectives is shown in Table 2.8.1.

2.3. Method

2.3.1. Research design and settings

To explain how entrepreneurs and communities influence each other towards firm/market creation, I chose qualitative methods and followed an inductive approach with multiple case studies (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). Theory-building methods play an important role in advancing research on emerging industries, as suggested in Forbes et al. (2011) citing Edmondson and McManus (2007), it is necessary to attend to "rich, detailed and evocative" data that require qualitative interpretation and are suitable to answers how and why questions.

This study looks at how the communities are involved in these early stages of the market before legitimization occurs. Therefore, time is a critical factor when investigating the process of market creation and similar to previous studies that look at value creation, legitimization and identity creation (Khaire, 2014; Navis and Glynn, 2010), the study follows a longitudinal approach. The study period starts from 2003, when one of the pioneer organizations was founded, to 2014 when there are signals of a widespread acceptance. Figure 2.8.1 shows the time line with origins of OSHW and the study period. Indicators to show the acceptance of the market are the widespread commercialization and consumer adoption of the products (Navis and Glynn, 2010) and the establishment of the Association for OSHW, as indication that 'institutional structures' have emerged.

The setting is the emergence of organizations that sell open tangible products. In this setting the business environment is extremely ambiguous, with lack of industry structure, rapid adoption and diffusion of technology. By free revealing a design in a community, the role of 'manufacturers' change to mainly physically make multiple copies of a given design (production) and the transfer of new designs to users who do not want to design themselves is less frequent (Baldwin, Hienerth, & von Hippel, 2006). According to the Open Source

Hardware Association (OSHWA, 2015), "OSHW is a term for tangible artifacts — machines, devices, or other physical things — whose design has been released to the public in such a way that anyone can make, modify, distribute, and use those things".

The OSHW firms produce micro-controllers boards. Proprietary versions of microcontrollers have a higher price and were not easily affordable to mass population. Despite facing skepticism due to the lack of patents for protection, the number of projects and firms selling open tangible products has grown considerably (Figure 2.8.2). Firms are having more than one million USD in revenues and in 2010 roughly a dozen start-ups made $50 million (Adafruit, 2010) and contrary to software ventures OSHW ventures do require manufacturers and sponsor or join communities.

Additionally, OSHW firms sponsor communities outside the boundaries of the firm, also known as firm-hosted users communities (Jeppesen and Frederiksen, 2006). And have firm-hosted platforms where users freely discuss problems using the products in their projects, ask technical or general questions and share their projects. In order to be able to sponsor or to join autonomous communities firms have to guarantee high levels of transparency and provide accessibility. Transparency refers to the quality and quantity of information revealed whereas accessibility is the possibility to participate in product development (West and O'Mahony, 2008). OSHW differs from OSS in the hardware component, which adds another issue, replicability that refers to the availability of components to produce the good (Balka, Raasch and Herstatt, 2010).

Regarding the integration of improvements suggested by users, OSHW ventures maintain control over the product though considering suggestions from the community, thus their communities are closer to user communities, with a stake in the developers' communities, as software is an important component in the products.

2.3.2. Data collection

Apart from the activities and behavior of individual entrepreneurs and their firms, to explain what happens during industry emergence it is necessary to identify specific actors at various levels whose interactions are most likely to matter (Forbes et al., 2011). Given that the interactions with user communities are of great significance to market creation, for the sample I selected firms based on the following criteria: (1) The organization develops hardware products, (2) the products developed are under an open source license and due to

the longitudinal design of the study, 3) the organization is still in activity with a history of at least three years in the market and 4) the organization relates with a community. To have a within variability in the cases, I considered the location and the ownership of the firms, which provides differences in background of the founders and communities, as well as referrals from founders of the cases were taken into account. One of the cases did not comply with all the criteria, thus the final sampling consisted of four case studies.

Previous research that review interactions of firms with sponsored communities has compared the Intellectual Property (IP) they use, the development model and community governance (West and O'Mahony, 2008). I focused on social and cognitive mechanisms that facilitate the understanding of the products and create awareness, pre-conditions for the acceptance of the market. To collect the data, I gathered information from publicly accessible sources. I did a search with the names of the selected OSHW companies as key words in Factiva database. I also collected information from key industry publications such as Wired and Maker magazines retrieved online.

The archival data includes around 900 press releases with information from Factiva database, the websites of the four companies and blogs, and trademarks registrations from TMView database. I also participated in a couple of workshops attending major conferences and events in the field such as the 2014 OSHW summit, MakerFaire and Arduino day, Minimaker faires London and Torino. A summary of cases, sources and data collected is presented in Table 2.8.2. Entrepreneurs were interviewed in the media articles, which provided the source for the analysis of the vocabulary employed to describe the firms and products and how the entrepreneurs/firms identify themselves. Another point is how the media describes the firms and the market in general, whether it is considered independent or within related industries.

I also conducted interviews with six of the nine the founders of the four organizations, and other 17 interviews with users. Interviews with founders were conducted face-to-face, by phone, Skype and email and included open questions about the organization (e.g. number of employees, products), the interviewee (role and functions within the organization), the innovation process, customers and competitors. The interviews lasted from fifteen minutes to one hour, and were recorded with permission. The recordings were transcribed verbatim. Other questions were stakeholders' preferences, collaborations and for the founder of the

OSHW association questions about the evolution of the market. A summary of the interview sources is presented in Table 2.8.3.

2.3.3. Data analysis

To answer how entrepreneurs involve communities, I began with the entrepreneurial activities toward creating their firms and the market. For each case, I departed from how entrepreneurs set the cognitive framing (Khaire, 2014) and mechanisms (Giarratana, 2004; Santos and Eisenhardt, 2009). Then I extended the analysis to the communities and other actors involved. Although the description is sequential, it was an iterative process, going back and for, from data to theory and the model proposed.

The first step involved the identification of entrepreneur's means by which they start their firms and gain the commitments of other actors (Sarasvathy and Dew, 2005). I began by examining entrepreneurs' previous experience (Benner and Tripsas, 2012), their links (e.g. to educational institutions and supplier hub) and other actors involved. Then, a next step was to proceed with the identification of the cognitive framing, for that I ran a word frequency analysis on all the articles that mention the firms of the case studies with the help of QSR NVivo 10. I constructed tables manually to compare the vocabulary employed to describe the firms and products (see Appendix A-Table A.2). The list of words was selected based on the name of the firm, founders' name and labels commonly used to define the product/industry, e.g. hardware, open source, electronics. In addition, I identified representative quotes that confirmed the use of templates and other identity mechanisms that entrepreneurs used.

Awareness is a construct that contributes to the definition of the market. Firms spread symbolic stories to raise awareness of the firm and its market (Santos & Eisenhardt, 2009). And the press evaluates and provides status to products, which shapes the perception of the customers about firms and the market (Khaire, 2014) and its viability (Navis and Glynn, 2010). Thus, I identified representative quotes about how the firms were portrayed by the media in the period between 2006, when the new ventures started to appear and 2014, four years after the OSHW association was founded (2010), to have a bit of buffer to observe the evolution of the market. I complemented the media representation with Google trends as a proxy for awareness, level of interest and appreciation regarding the firm. This online tool shows how often a particular search-term, in this case the firms' name is entered

relative to the total search-volume across various regions of the world during a past period (See Appendix A- Figure A.1).

To investigate the relationship between firms and user communities, I reviewed information exchange in blogs and forums at the organization web sites, which are publicly available. The archival data was triangulated with the information from other sources, founders and other stakeholders' interviews and field notes from the participation in the conferences and workshops. Finally, I did a cross-case comparison to help with the *pattern clarification* and see the aggregate level of evidence from the case studies (Eisenhardt, 1989). I rated the firms' use of mechanisms and how the community was involved in the firms' activities. The rating on the use of the mechanisms is as follows, I gave a score for the use of a particular action and if a firm was particularly early and proactive in using this mechanism. Higher scores were given when the actions of the entrepreneurs involved the community and/or got responses from its members. The details are presented in Table 2.8.4 and Table 2.8.5.

2.4. Findings: The co-creation of firms and the market

After analyzing the data, the findings suggest that entrepreneurs in the highly ambiguous and uncertain market niche of open source microcontrollers built/joined user communities and engaged in activities with them, which facilitated the emergence of firms and markets. There are other actors involved but the study focuses on activities with user communities that unfold over time, which I organized into phases: *clarifying products and firms*, *capturing the market* and *formalizing the market*. The first phase includes actions of the entrepreneurs intertwined with those of the community to shape a unique identity. The identity formation allows the firm to clarify the product and the firm so that market audiences understand them. The second stage supports the development of the firm and formation of reputation that capture commitments. There is a third step, *formalizing the market*, which describes events that mark the new market's acceptance.

2.4.1. Clarifying products, firms, market

When entrepreneurs are first to market, there is a lot of ambiguity and uncertainty. There are no rules to follow and entrepreneurs have to answer questions for users but also for themselves about who will be the suppliers, who will manufacture the products (tangible products), who will be the potential customers, etc. The following quote illustrates how the lack of standards, processes and licenses predominated in the nascent OSHW market.

> ***At the beginning the you know on the whole question on open source hardware, open hardware, open source, you know still very, very complex, very complex situation, still not very defined in the standards, licenses or processes***. *For us at the beginning it was a specific need, we knew the school was closing and we were afraid that lawyers will show up one day and say "Everything here goes into a box, and gets forgotten about". So we thought, ok if we open everything about this, then we can, we can survive the closing of the school, that was the first step, then* ***we had to figure out that there is a way to get a very nice ecosystem of people participating, and making extensions, making derivatives and helping***. *(Founder & CEO Arduino)*

The fact that firms put their product designs available to the public helped their customers to understand the products better. However, the data indicate that to cope with the lack of rules, entrepreneurs had to define and frame new guidelines about the products to be sold and new ways of doing things. To diminish the ambiguity in the first stages, entrepreneurs use the available means they have ('who they are', 'what they do' and 'who they know') and complement their means with the use of identity mechanisms to establish firms' identity. The use of identity mechanisms, e.g. *adoption of templates* is familiar in the creation of market creation literature (Navis and Glynn, 2010; Santos and Eisenhardt, 2009). Arduino followed this pattern closely. Its founders a group of academics, developed the initial product working in a school in Italy. After testing the prototype in their schools with their students, in 2005, the team decided to make the product open source and named the new firm Arduino. The software and hardware elements that form the product were already open source.

The adoption of an open source template, a cognitive related area that applies for software, provided a frame to understand what the firm stands for and the familiarity to grasp what the organization is about. Then the focus shifted to make clear how the products could be

used for and targeted a specific group of users. The templates adopted were very similar across cases. Looking at the wording mentioned in the media, when interviewing founders or reviewing products (See Appendix A-Table A.2), the vocabulary employed to describe the product is a mix of both open source and electronics, mostly related to computers, i.e. software and hardware. Arduino uses the word 'hardware' and 'project', which are connected to the open source model of production.

In similar way, SparkFun founder is an engineer. The vocabulary used for describing some of it products contains 'device', 'board', which are words from electronics and the computer world. The idea of a market for OSHW products was unknown and when SparkFun's founder describes the firm, he does not include specifically the word 'open source' as the venture also sells proprietary products, but stressed transparency. Its customers originally comprised students in engineering and makers with high-level expertise, however by sharing free available tutorials that explain how to use materials or construct kits, new non-technical customers joined its community.

The founders of BeagleBoard also engineers, followed the same pattern but with a different approach. They developed their professional life within a big corporation-Texas Instruments (TI) and founded the BeagleBoard Foundation while working there. Despite their explanations about the Foundation's self-sustainable operations, the media covered the strong connection with the corporation. BeagleBoard adopted a well-known template from computers. The founders defined the product as a 'single-board-computer design', 'embedded system' and 'laptop-like performance', running 'Linux' operating system. This wording employed to describe the product appeals to engineers and university students, who have advance knowledge in computers and electronics. Though the clarity of the product definition and users' target helped little to separate the new organization from being associated to the corporate sponsor.

Meanwhile, SeeedStudio founders are also engineers from China. Seeed incorporated improvements to existing OSHW products and made them cheaper by using the manufacturing network knowledge of its location. The terms coined for the new market were already available and SeeedStudio describes itself as a facilitator of 'open source hardware', manufacturer of 'experimental, niche-market products'. Its roots come from the Chinese, local, 'shanzai' culture of 'quick prototyping' and 'low-cost manufacturing',

terms that resonate to users called ‘makers’. SeeedStudio filled a gap between the makers and the supply chain, and shifted their activities to fill it and serve the ‘makers’.

Arduino founders’ identity as academics helped to test not only the prototype but also to introduce the product in educational institutions with new students, who were part of their academic network. They projected their network into the future and students became part of the user community, which was important to reach critical mass. Initially, the firm targeted people with no experience in electronics but with a common interest in using the products and/or services, e.g. designers, though the community’s composition evolves as the organization grows. Arduino founders originally appealed to students, artists and designers, who do not have deep knowledge in the engineering field but needed hardware and software as a medium to do their work. Arduino targeted non-experts (artists, designers as opposed to engineers), delimiting it from the communities already established around the technologies conforming the products and reinforcing its identity rooted in Education, as explained by one of the founders.

> *Arduino was conceived as a tool for designers and, in the end, it became a more general tool for all those interested in “do it yourself” technology, I think, because of low costs and (relative) easiness of use. The field was dominated by engineers who often created complex user interfaces and difficult to understand devices, in the name of the concept of technology as an elitist field, where you can enter just if you are a “wizard” of this religion. (Founder & CEO Arduino, Digimag 37 / September 2008)*

The approach of BeagleBoard foundation was to join an established open-source development community (Linux-UNIX). In this approach, the founders of BeagleBoard introduced a powerful high quality product that engaged and convinced members of the Linux group. The roles are clearly delimited; the hardware design and hardware support is done by the organization and the Linux community and third parties give the software technical support for the products. The philosophy of UNIX, which is an operating system that was built in an environment for playing games, is that members often work on something for the sake of having fun or that brings them pleasure and also allows for individual expressions (Gancarz, 2003).

In general entrepreneurs initiated communities with values based on open source and corresponding practices, i.e. sharing and exchanging knowledge and use of open source

licenses, feedback of users, etc., but SparkFun and Seeed Studio were vague in targeting a specific type of user. They serve users/makers. Makers are seen as an extension of DIY and hacker culture. The community is the source of feedback to their services and products and similar to other startups there was a lot of ambiguity about costumers.

In addition, entrepreneurs engaged in story dissemination and spread the word about their firms. The *storytelling* involves the narratives of entrepreneurs about the origins of the firm and background of the founder(s) and other details that enhance their reputation. The stories resonate well and strong enough to attract users and members to the communities. The cases illustrate this, Arduino's founders spent considerable time telling about the creation of the product in the north of Italy, a place associated with companies with a big tradition in design and innovation such as Olivetti and Fiat. The founders wanted to project this heritage to differentiate their products from electronics made in the USA or China, whereas SeeedStudio and SparkFun played to the charisma of the founder and the complications of building a firm from scratch. SeeedStudio story about the founder and its humble origins in China is not a striking one though entertains the audience.

Communities worked diligently and entrepreneurs promoted the projects done by the community as examples of what OSHW is and what the products can do. The documentation of the products and projects helped to replicate and understand how the product works. The understanding of product helped entrepreneurs to attract customers and members to the community, showing what they have to offer. Firms also developed social and educational activities and organization of events to unfold the community. All the firms mostly did workshops, training courses and contests. Some firms use the virtual platforms to created events even purely commercial to engage the community and to maintain the interest of members during the whole year, e.g. SparkFun 'free day', in which the firm offers prizes and discounts online, Arduino day to celebrate the birth of the firm, a SparkFun contest called Autonomous Vehicle Competition, with members of the community as well as employees conforming teams to participate.

2.4.2. Capturing the market

Firms employed strategies such as the use of *emotions* and *signaling leadership* to gain audiences. Firms had to *convince* them about its value and by spreading the word, get recognition and acceptance of the market audiences. Entrepreneurs used various ways to *signal leadership* to position itself as leader and some firms make adjustments to the

identity portrayed initially. SparkFun did not like the open source label at the beginning; the founder expressed his preference for the word transparency but eventually the firm accepted the label and fully supported OSHW and highlighted performance facts, its financial achievements in terms of growth, whereas BeagleBoard and Arduino played with descriptions to their products. BeagleBoard added to their definition the word 'community-supported', as the products use 'Linux', a technology based in OSS, developed by a well-established software community.

Arduino incorporated the world 'platform', which raised the level of the product from a single microprocessor to a family of them with an integrated development environment (IDE). It stressed versatility and usability to the 'Maker' community. Meanwhile, SeeedStudio convinced audiences by association, high profile organizations in the new market recognized its work of reproducing OSHW products. Some firms added market reach (customers and countries) and participation in important events. SeeedStudio's founder participates as speaker and organizer in international events, which gave the firm high visibility in western countries.

The communities complemented those activities with *replicating* the stories and participatin*g* in technical support and discussion and moderation roles. Members volunteer for various tasks, taking informal responsibilities such as moderation of discussions. The organizations in turn select and incorporate needs/improvements originated in the community to products. The adoption from hackers and makers contributed to the popularity of the products, increasing the collective collaboration and international support. Not all the communities responded equally. SparkFun and Arduino communities are visibly more participative and the firm assigned moderator roles to users, whereas Seeed Studio faced difficulties to maintain the community happy, initially they could not motivate users to support and foster technical discussion in the forum. An in similar way, the interactions between BeagleBoard and its community were based on mostly on technical issues, but when requesting general opinion, the community was less responsive.

Emotional cues facilitated adherence of members and to certain extent endure higher levels of control and reinforce commitments, the data suggest that entrepreneurs utilized emotions to create social meaning through *emotional appeal* by sharing good and bad experiences. The frequent posts in firm/founder's blogs, sharing good and bad experiences, legal issues, manufacturing mistakes and relevant social issues (e.g. gender debates, internet regulations)

was key to generate an outpouring of sympathy and sharing the news online in blogs or other channels, as we can see in one of the members' response to the post:

> *SPARKFUN … it's not just a name!*
> *It's the definition of what this company provides.*
> *I proudly support SPARKFUN and am grateful for all the products, support, and education they provide to customers and communities (Community member, in response to 'SparkFun gets a Cease and Desist Letter' Blog, 2009).*

Activities such as learning, sharing, attracted members to the community and firm and provide a social value that is transformed into an economic value for all the stakeholders as products gain reputation and the preference of customers. The pioneer firms (Arduino and SeeedStudio) were more pro-active on building the community than latecomers (BeagleBoard and SeeedStudio) that is reflected in the number of followers in their websites and social media groups. However, there is an aggregate effort from each individual firm defending the values of the community to delimit the market and the communities' actions are intertwined with those of the entrepreneurs.

2.4.3. Formalizing the market

Finally, formalizing the market phase includes events that marked the acceptance of the firms and market. The first event is the creation of the OSHW Association. Early efforts in the creation of the OSHW market, long before the appearance of current firms conforming it, took place in 1999, when the Open Design Foundation wanted to extend open source to machine designs (Vallance, 2001) and later in 2007 the Open Hardware Foundation, a nonprofit organization was created to safeguard the interests of Open Graphics Project community. However, it was until 2009-2010 that OSHW firms self-organized to create the OSHW Association, a nonprofit entity that reached a collective agreement on the standard definition(s) and discusses best practices (OSHWA, 2013).

Everybody can refer to the standard definition in order to comply and every year there is an OSHW summit, in which they discuss the affairs of the market. To illustrate its influence, during one of the conferences BeagleBoard's founder addressed the public about the membership to the OSHW community, based on the differentiation argument of what constitutes an OSHW product. His purpose was to clarify the customer perception and reinforce the values of the market against new entrants with partially open products that have grown in popularity since the came on the scene such as Raspberry PI.

Secondly, the inclusion of OSHW products in the curricula of schools and universities, introducing and teaching the products to new generations was an important milestone that helped to consolidate the acceptation of the market. Arduino and SparkFun are particularly interested in working with education, by developing products, kits, providing training material and/or training services. Seeed Studio started to sell hardware kits to schools and partner with them in order that students visit its makerspace. And BeagleBoard (BB) Foundation in collaboration with TI has given workshops in universities in India and TI donated BB microprocessors.

A third aspect is the engagement in partnerships with both external firms and firms within the niche. The purpose of partnerships was the creation of innovations and a demand for them. Partnership between ventures that produced OSHW products reinforced the market in the mind of diverse groups of users. Competitors (i.e., startups aiming to sell to the same users) came together to collaborate in the creation of new products. The formation of partnerships between players within the market was a natural next step for new product development. Arduino-BeagleBoard created Arduino Tre and SparkFun and SeeedStudio partnered with new startups in the market, transferring know-how and filling the gap in the need for services to manufacture OSHW products.

These partnerships also enlarged the community base of both firms and strengthen bonds among ventures in the markets and the community. With the firms' partnerships, they gained exposure to each company's followers. The firms' reputation was already established, thus joining skills and knowledge builds on the strengths of both, extends the scope and the collaboration of their communities and provided more credibility to its mission, the diffusion of OSHW. Also firms' partnerships with prominent firms such as Texas Instruments, Intel and Microsoft did not seem consistent with the values of the community, which showed signs of discomfort, externalized in forums. Criticism eventually faded, the founders put forward the argument that OSHW firms were making the world more open and convincing corporations to follow the openness rules. The transference of prestige and influence was in both directions, so that they could reach a larger community and deter competitors.

Finally, the increasing appearance of clones and derivatives that came from people who were aware of the product possible members of the communities is part of this formalization. A derivative is a product design altered or modified by another person or

company from the original product and a clone is a copy of an OSHW product (Gibb, 2014). Clones and derivatives appear when they realize that there is a market, as the following quote illustrates:

> ***At the very beginning, we didn't have a problem with people cloning Arduino because there wasn't a market****. People didn't really care. And most of the people we worked with-- first, they didn't even know how to make a PCB. So for them to be able to buy a PCB was already good, let alone assemble SMD circuits. So the fact that you could have an available and SMD assembled circuit, that you would just plug into a computer, and it would work, was the selling point. (Founder & CEO Arduino, 2005)*

With the increasing number of entrants, the firms used differentiation mechanisms, through the use of trademarks to protect their identity ('who they are') and the quality of the products. The Arduino founder exposed the clone-products in the company blog and threatened to take legal action when those copies have the logo or name printed on the product. The members of the community responded by monitoring and reporting replicas. The narrative of SeeedStudio aimed to convince about the benefits of 'copycat' of made in China, that copy happens to understand a product in order to innovate. While SparkFun takes it as the firm has to increase the pace of the innovation. The less affected organization was BeagleBoard as it is a non-profit.

All the steps and corresponding mechanisms are described in Table 2.8.6. And Table A.4 in Appendix A contains illustrative quotes of the mechanisms.

---INSERT TABLE 2.8.6 HERE---

2.5. A model for firm-community involvement in firms/markets creation

Based on the findings, I developed a conceptual model with three steps. The two first steps include actions, activities and policies that firms do to establish a relationship with one or more target communities (Dahalander, 2007; Fosfuri et al., 2011). These actions are reciprocated by the community and the resulted firm-communities' interactions support the born of firms and market, they are organized in three sets. The third step in the model is included only to mark the acceptance or formalization of the market.

The first set of interactions includes three identity-related interactions that facilitate firm and market understanding, the second set comprises interactions related to the formation of a reputation that facilitates awareness and the perception of worth. The last set contains two interactions linked to source knowledge from the community. It is positioned in the middle of the two main steps to indicate that these set of interactions equally support the identity and the reputation formation. The model is presented in Figure 2.8.3.

2.5.1. Firm, product and market understanding (Identity related interactions)

Given the uncertainty and ambiguity of new markets, a lot of the effort of entrepreneurs goes to define a unique identity (Santos & Eisenhardt, 2009). But entrepreneurs engage in identity related interactions with its user community, which refer to those activities that help to build a collective identity. A good practice is that firm's actions should be congruent with the values of the community, which facilitates a deep integration (Fosfuri et al., 2011). As it is known in studies of sponsored communities (IBM and Eclipse) when a project fails to convince as truly open source, the price is paid in the contributions (O'Mahony, Cela Diaz, & Mamas, 2005).

Prior research OSS is vague in the antecedents of community formation, the assumption is that by releasing the code and assigning resources the community will form (Dahlander, 2007; West and O'Mahony, 2005). User communities formed in early stages of the market were influenced by the entrepreneurial identity, i.e., entrepreneurs means: 'who they are' and 'what they do' and their existing networks, which often dictate a target user group, e.g. if the founders are engineers, their potential customers more likely would be engineers with similar interests. Entrepreneurs are able to persuade target groups to collaborate because of the entrepreneurs' attributes and their identity.

Yet entrepreneur's identity also becomes interweaved with targeted groups of customers. When founders initiated (created/joined) their user communities and decided to do open source products, they capitalized on preexisting goals and adopt values of the movements that those groups associate with (OSS, Do It Yourself-DIY, Hackers). The OSHW values are aligned to the OSS movement and in essence to the characteristics of the hacker culture such as consciousness of kind, shared rituals and traditions and a sense of duty and obligation toward the community as a whole. Those values became markers of OSHW

community as well as the firms, thus the communities served as reference groups that help to articulate the kind of practices they do or not do (Chen and O'Mahony, 2009).

Firms put a lot of effort into explaining the new products and firms. Entrepreneurs do any necessary action to get legitimacy, one strategy to achieve this is to establish a niche with a distinct 'oppositional' identity and. Examples are craft beer against the mass-produced beer (Swaminathan and Wade, 2001) and OSS ventures that formed an identity based on the rejection of the dominant culture regarding traditional proprietary software. All those particular features provide a sense of identity to new members. New entrants assimilate the values of open source movements and communities (Chen and O'Mahony, 2009). The values of the user communities summed up to entrepreneurs' identity and transformed it into something that members of the community identify with, through collective experiences (Rao, 2009) with the products and with the events and situations of the entrepreneurs/firms.

Explaining products, firms and market

To name new industries is important to create a label "distinctive enough to convey the novelty of the underlying product and attract the attention of stakeholders, and familiar enough to be easily comprehensible" (Grodal et al., 2015, p. 429). Previous research suggests that adopting templates and vocabulary from very proximate markets will lose some of the intrigue and harm the perception of having a distinct identity (Santos and Eisenhardt, 2009). My findings, however, suggest otherwise, that firms adopted from a nearby market template, the OSS in their label words for the descriptions of products and missions. This provided familiarity that assisted the market audiences in get the understanding of complicated products.

On top of that, founders used projects developed by the community as examples of how to use their product, which are not limited by the idiosyncrasies of the ventures' founders. Communities like other stakeholders such as the media and educational institutions co-create meanings that translate into shared understandings of identity (Khaire and Wadhwani, 2010). By sharing results and know-how firms facilitate that users experiment with the new product and through this they built a connection among them.

Innovations often challenges current norms, values, social practices and relationships (Rao, 2009), therefore the understanding of the firm and product is very important so users can make sense of the emerging industry (Grodal et al., 2015; Santos and Eisenhardt, 2009). In

the creation of a market, a collective identity is used to generate sales, to bolster employee morale and even to generate opposition (Rao, 2009). Initially, the media compared OSHW products with existing proprietary products, e.g. Parallax's Basic Stamp. All the cases practice the freely exchange of information, which differentiated them from the existing offering and also by the lower price. Users took up those projects and became part of the community. The open source provided the basis to signal a community effort but firms still had to define what open source for tangible objects meant.

Besides entrepreneurs explaining the products and firm to external audiences to get their interest, people could identify with a group and share beliefs and interests. Different groups experiment with the products to fulfill their needs, in the OSHW market, engineers, designers and artists understood whether the product could be used in their projects. The media and other external audiences could grasp the idea that hardware products could be the result of a firm-community effort. Understanding how users could use the products and in essence what the product is, contributed to the sense giving about 'what we do'. By using the new products in projects and acquiring of know-how to use them, the community contributed to build and consolidate commitments that co-created the identity for new organizations and the market, this suggests the following proposition:

> *Proposition 1. Firm-community interactions that use identity-based mechanisms (i.e., entrepreneur' means-community's values, templates-know-how and org. social events-community's participation) are more likely to increase the understanding of firm, products and market by market audiences (e.g. press, suppliers, users, etc.).*

2.5.2. Awareness and perception of worth (Reputation related interactions)

Reputation related interactions are those interactions that contributed to enhance the awareness of the products, firms and market. Reputation reflects the perceptions of stakeholders based on firm's demonstration on its ability to create value, e.g. producing quality goods; and the prominence of firms in the minds of stakeholders (Petkova, Wadhwa, Yao, & Jain, 2014; Rindova, Williamson, Petkova, & Sever, 2005), thus reputation is socially constructed and influences the survival of organizations (Rao, 1994).

Entrepreneurs tried to convince audiences about their competence with awards and benefits or quality of the product, the reduction of cost and/or the argument of overall common good

of free revealing. Other actions to signal leadership include promoting firms' achievements regarding size, revenues and the quality of products to convey superiority and awards. This is aligned with previous research of entrepreneurial firms (Santos and Eisenhardt, 2009). Yet the community actions enhanced the reputation by helping to propagate faster an enduring image of the firms. Community members shared firms' message outside the boundaries of the firm, posting and linking the message over the Internet, enlarging even more the audience. Also users share experiences of their own projects, adding to the firms' stories about the product.

One of the challenges of entrepreneurs is to have the ability to gain commitments, especially from stakeholders that expect non-pecuniary benefits. Entrepreneurs use the dissemination of stories that appeal to the values of the community to gain the favor of users. Having a message that conveys social meaning and enable emotional connection, makes the message sticky (Szulanski, 1996). Stories that appeal to emotions and convey sympathy, spread a more everlasting message, winning the mind and the heart of current and potential users.

The arousal of emotions has been noted mainly for the articulation of causes or goals (Rao, 2009). However, the firms can use *emotional appeal* in quotidian interactions too. The power of emotions to influence judgment is sparked by firm's situations such as facing legal issues, mistakes, challenges of being open, etc. The sharing of those experiences by founders in blogs and forums spur the response of users. Emotions can influence interactions of stakeholders with the firm and get coverage from the media and in general public attention (Rindova, Pollock, & Hayward, 2006). By using *emotional cues*, entrepreneurs engaged in a dialogue with members of the community.

Community members participate in OSS projects in various activities among them generation of public awareness, marketing, product, development, support and business development (Bagozzi and Dholakia, 2006; West and O'Mahony, 2005). The activities of the communities in OSHW are similar, but the type of product and materiality of it lead to dissemination of information of what they could do with the product, posting and sharing projects in blogs available to friends and the public domain. The technical abilities were important for support but it is the willingness to help and the easiness to use products rather than advanced knowledge that facilitated adoption of the products by non-electronic people (artist, designers and children), which contributed to attract users.

Apart from face-to-face participation in annual events (Maker Faire, competitions, workshops, etc.), firms set up information platforms (forums, software development websites) where they organize, interact and influence the community. This infrastructure effectively became the locus of value creation (Ramaswamy and Ozcan, 2004) with feedback and knowledge exchange that feed incremental improvements or new innovations, vital for survival in a fast changing environment. The mailing list are the effective level to request improvements and changes, while the forums are the medium that users employed to express, have a voice and respond freely to the firms. The members of the communities expressed loyalty feelings, desire to buy firm's products and engaged in informal activities related to the firm and products like monitoring, reporting clones and writing posts to defend/justify firms. All those micro-processes have an impact in the perception of audiences.

Responsiveness and support help firms to earn an outstanding reputation. However, there were differences among the communities. For Arduino, limitations in terms of language provoked that community members volunteer for support in their language (French, Spanish, etc.) and technical expertise. The responsiveness and willingness to help of Arduino community members were noticed and reported by the media and the users and acknowledging the value of this behavior. This pattern was identified also in SparkFun and to a lesser extent in Beagleboard, perhaps because it is an autonomous community and the higher technical skills required to use its products. In contrast, SeeedStudio had difficulties with the user support and had to establish additional incentives (points system) for members of the community to participate.

In uncertain environments, firm's reputation enhances chances of survival by helping to distinguish firms from peers and to be viewed favorably relative to an ideal standard (King and Whetten, 2008). And the generation of favorable perceptions among a broad set of audiences facilitate acceptance (Mezias, Lant, Mezias & Miller, 2010). For OSHW startups with new market-creating innovations, reputation facilitated that market audiences could recognize and buy the new products. Details such as price, quality of products, production in small quantities and problems are among the features of the new market discussed in firms and community forums. The community echoed the market's features, spread the word and engage in actions that got noticed by external audiences, media, potential users, which made firms very attractive.

Firms' reputation is important to convince users, potential employees, suppliers, etc., but the social interactions among members in the community extended the social influence and more people started to pay attention to the new market. The corresponding proposition as follows:

> *P2. Firms-community interactions that use reputation-enhanced mechanisms (i.e. storytelling-community's replication, emotional appeal-responsiveness and leadership signals-community's skills, enthusiasm) are more likely to achieve higher levels of awareness and perception of worth for the product/market in the mind of market audiences as compared to firm only strategies.*

2.5.3. Knowledge sourcing interactions

Knowledge sourcing interactions are important sources of knowledge about users' current and future needs. Knowledge sourcing outside the firm fosters innovative outcomes (Chesbrough, 2006) and firms can get the resources and technical skills relevant in the development of technological products of a new market/category (Haefliger, Jäger and von Krogh, 2010). However, unless the knowledge is strategic, sourcing is not necessarily advantageous; it could be time-consuming and demands attention (Einsenhardt and Santos, 2002; Laursen and Salter, 2006), even more many product innovators fail to link technological issues to market related issues (Dougherty, 1992).

Knowledge sourcing interactions generate user knowledge about current products and future needs, i.e. the new market potential. In nascent markets, knowledge changes fast, is sticky and difficult to validate, the use of the products provides users with informational advantages (e.g. valuable features, how the products work with other products, etc.), so users articulate the needs about products and help to generate interest that ultimately allows the creation of the new market (Shah and Tripsas, 2012; West and O'Mahony, 2005). Accessibility to product's information and the creation of their own projects with the product allow community members to detect problems, recombine ideas and develop new functions. Additionally, community members help other users in forums and voice future product wants and although firms take the final decisions, both firms and user community converge towards a common perception of what is valuable (Dahlander, 2007; Dahlander, Frederiksen, & Rullani, 2008).

The users' feedback allows entrepreneurs to select new goals that enrich their identity and helps to distinguish the firm and the market, e.g. Arduino got from its users the interest for new developments towards robots and Internet of things. SeeedStudio identified problems of Arduino's product from users and launched its own improved product. SparkFun periodically reviews users' demands to create and launch products and extended its existing business to building kits and to education. The product and user knowledge generated are a key source for renewal, something that strengthen the ability to create value (Rindova and Fombrun, 1999).

> *P3. Firms-community interactions that support knowledge exchange are more likely to provide knowledge about users' current and future needs and consequently strengthen the ability to create value.*

2.5.4. Market acceptance

The previously described sets of interactions explain actions of entrepreneurs and community members that have an impact on the market emergence. This reinforces research stating that sustained social interactions with communities can become intangible assets and a source of competitive advantage (Fosfuri et al., 2010; Rindova and Fombrun, 1999). But before that happens, firms have to learn how to manage the relationship with the community and to develop the ability to convene community members to participate, to gather feedback and to select improvements without alienating the community.

In the creation of markets, there are elements of judgments, evaluation and social construction of reality. However, in high uncertainty and ambiguity environments, the bases for comparing products are as unclear as the relevant knowledge about the firms to be evaluated (Navis and Glynn, 2010; Khaire, 2014). Entrepreneurs provide a cognitive framing but the constant interactions of relevant actors generate a shared understanding of the product/market and its value (Khaire, 2014). This happened with OSHW firms and their communities. The firms grew with the community and vice versa. The user communities became relevant actors, actively participating in the creation of value.

The ongoing interactions improved the chances of success (West and O'Mahony, 2005), by providing the means to understand the functions and the utility of the products. And when actors do not question the usefulness of a new product or the value of the industry it represents, the new industry is accepted or taken for granted (Rao, 1994; Zucker, 1983).

The evidence of a shared acceptance of OSHW goes from products included in the schools curricula to the increasing offer of clones and derivatives. Derivatives can create confusion in users, but a strong identity helped to distinguish between boards of similar or identical design from different producers (Mellis, 2014). The corresponding proposition as follows:

> *Proposition 4. New entrants that over time proactively engage in identity, reputation and knowledge sourcing related interactions with communities are more likely to achieve the acceptance of the market by market-audiences.*

2.6. Discussion

Prior research on market creation has found strategies based on dominance using cognitive and competitive mechanisms (Santos and Eisenhardt, 2009) and use of mechanisms such as identity that facilitate the social construction of it (Khaire, 2014; Navis and Glynn, 2011). In a way those studies consider both internal (entrepreneurial) and external (audience) factors. However, this study differs from this body of research in the peculiarities of firms producing physical open source products and in the inclusion of user communities, actively involved in the construction of the market. They play a different role than other types of communities such as financial security analysts and market investors (Navis and Glynn, 2010). I propose a framework based on a co-creation approach (Ramaswamy and Ozcan, 2014) that shows how firms actively engage with user communities through constant interactions. The interactions are linked to three aspects that influence the perception of value and ultimately help to the acceptance of the market: 1) enhancing identity, 2) earn reputation and 3) knowledge sourcing.

Furthermore, the ambiguity of nascent markets and the fact that new entrants do not have established practices are two conditions under which the co-creation of an identity with communities (Fosfuri et al., 2011) would help entrepreneurs. It benefits the organization not only to create or/and to improve the products faster and at a lower cost, but also to gain reputation, which helped to the awareness of the market as whole. Regarding reputation, firms demonstrate its ability to create value by producing quality goods (Petkova, Wadhwa, Yao, & Jain, 2014; Rindova, Williamson, Petkova, & Sever, 2005), the findings suggest that the enhancement of firms' reputation also happens through firms association with communities. The technical ability and willingness to help of community members increase the reputation of firms to the view of the market audiences.

Two outcomes of this study differ from findings in previous research on market creation. The first one is about the 'means' or entrepreneurial identity, i.e., the 'what we do' and 'who we are'. In Navis and Glynn (2010)'s study in which the attention of audiences go to 'what we do' as members of the market, then as the markets grew and was legitimized, the attention shifted to the organizations' identity, used as a differentiation mechanism that describes 'who we are', so the firms differentiated themselves from other firms. In contrast, for all the cases in this study both means were equally necessary to understand the product and firm early on, as they have to convince participants in the community and the fact that the firms were using a familiar template (open source) might explain the temporal differences. The second difference is about the use of templates, contrary to the suggestion that they should be from distant fields (Santos and Eisenhardt, 2009), in this study the use of familiar templates was necessary to understand the products/firms.

Examining a niche market for hardware that requires upfront financial investments to produce tangible products suggest other approach for OSHW. In contrast to previous research that considers OSHW as equivalent of open design, in which different actors (firms, individuals, etc.) collaborate within a development process to produce a physical artifact (Balka et al., 2010, Raasch et al., 2009a), in this study the OSHW ventures do not open the design process. Firms release the information until the product launch, though the OSHW ventures' strategy to sponsor communities it is based largely in the implementation of systematic practices and regular engagement by providing platforms to access knowledge of communities that becomes the locus of value creation (Ramaswamy and Ozcan, 2014).

Established firms in mature markets have implemented platforms, but this practice extends to new ventures and new markets as well. OSS ventures founding a community have to provide an infrastructure for interactions, which allow them to screen new developments (Dahlander's, 2007). With the exception of BeagleBoard all the cases were very proactive about providing means for interactions and the knowledge sourced was used as a guide for the market, with the firms retaining the control about what to include in future releases of products. This has management considerations for the firm regarding the establishment of incentives and the availability of resources to manage the community that should be further investigated.

Finally, I go beyond the argument of whether individual firms or collectives are the drivers behind the construction of markets and see it as co-creation process. Firms engage with communities in very early stages, when there is a lot of ambiguity and uncertainty, so both individuals and collectives are important to make sense of a new reality. There are other actors (Media, educational institutions, etc.) participating in the sensemaking of the market that do not appear in the analysis, but for tractability reasons and to demonstrate that the participation of the user community was paramount for the articulation of value, the attention concentrates on the relationships between firms and user communities developed overtime.

On the one hand, the product itself is an element of value for users in various senses, a product is acquired not only for its functionality but also for its identification content, when the users participate in its creation, it generates loyalty feelings and willingness to cooperate from the community members and reputational capital (Fosfuri et al., 2011). Though not all the products enjoy the same symbolic value, the products of one of the firms became symbolic, a manifestation of community values, even when the firm selects the products' features to be included and decides when it should be released. Many OSHW ventures piggybacked on the name of the symbolic product and its name.

On the other hand, by pro-actively building a relationship with a community, entrepreneurs enhance their ability to persuade audiences and forge a unique identity that attracted users and developers, created first-mover advantage and lock-in effects (Dahlander, 2007) and increased public awareness (West and O'Mahony, 2005). The repertoire of interactions presented in the framework constitutes a community-focus strategy for the co-creation of markets.

2.7. Conclusion

The study aims to understand how communities and entrepreneurs activities converge into the creation of firms and markets. The study contributes to the literature on market creation (Forbes et al. 2011; Khaire, 2014; Navis and Glynn; Eisenhardt and Santos, 2009; Rao, 2009) particularly in the emergence of new ventures and markets in open source (Dahlander, 2007) by providing a framework that explains how entrepreneurs build and maintain the relationship with user communities (Fosfuri et al., 2011; O'Mahony and Lakhani, 2011) and participate in a co-creation process that facilitates the market acceptance. The two-step process (clarifying products and capturing the market) comprises

the mechanisms used by the entrepreneurs and the actions and reactions of their communities.

This approach mirrors the social construction of market perspective taken by other scholars (Khaire, 2014; Navis and Glynn, 2011). Adding user communities as an active participant in market creation accounts for the variety of organizing models (O'Mahony and Lakhani, 2011). The model shows how the user community actions complement organization activities and co-create the perception of value. The repertoire of identity, reputation and knowledge sourcing related interactions between firms and communities delimits the role that communities play in the emergence of markets. Firms and communities were able to define their corresponding activities, albeit informally. Clarity in the division of labor, roles and interdependencies are important for the market to emerge (Ozcan and Santos, 2015). Additionally, the case studies show a model of collaboration in OSHW different from the open design process for the creation of a physical artifact, in which diverse actors participate (Raasch et al., 2009a). All the case studies use free revealing only when they have the end product ready to launch.

The managerial implications are that entrepreneurs venturing in nascent markets should recognize the potential opportunities of building a close relationship with user communities. Firms that initiate a community should provide appropriate incentives and assign dedicated resources for the community from the beginning and pro-actively co-develop an identity. Information sharing should not be limited to technical or product issues, firms should share events or situations that involve emotional appealing and that add to the authenticity of their engagement and motivation to action.

Limitations and further research

One of the limitations of the study is that all the chosen cases studies are successful OSHW organizations in the same industry, though there are intergroup differences among the cases and different starting conditions. It is difficult to trace and find sufficient data of startups that failed (e.g. Openmoko). Additionally, the open source context indicates a particular behavior of firms and communities. Further work would be necessary to increase generalizability and find out the dynamics of more competitively intense markets using patents or with participation of incumbents.

Yet the applicability of the results within open source domain might be extended to other industries like automotive, telecommunications and even biotech. For instance, Tesla Motors free revealed all its patents in 2014 for the advancement of electric vehicles (Tesla, 2014). Furthermore, user communities exist outside open source and are becoming increasingly important in other industries, for example music, videogames, sports and fashion (West and Lakhani, 2008) and contribute to the recombination of shared knowledge in diverse domains such as artwork, encyclopedia entries, science, etc. (O'Mahony and Lakhani, 2011).

Another limitation is that the cases started before the advent of crowd-funding platforms (e.g. Kickstarter), which are tools that facilitate not only the access to financial resources but also the pre-forming and enticing of potential members for a community formation. Another avenues of research are to investigate how firms not compliant with the rules of the market (e.g. Raspberry Pi) are considered part of the market in the minds of the audiences and how firms diminish their influence over the community (e.g. MakerBot).

2.8. Tables & Figures

Table 2.8. 1 Perspectives of the emergence of markets

Perspectives	Goal	Focal actor	Incentives	Impact	Strategies	References
Entrepreneurial action view	Causal Theories: opportunity discovered Effectuation: unspecific goal, entrepreneurs start with means	Entrepreneurs	Causal Theories: Potential economic opportunities Effectuation: Pre-existent preferences, docility, passions, convictions, self-interest, fun, even indifference	Development of new technologies, product or services	Mechanisms (leadership signaling, use of templates, dissemination of stories); Means: Identity, skill and social network; focus on controlling what is within entrepreneurs' possibilities	Santos & Eisenhardt, 2009; Giarratana, 2004; Benner & Tripsas, 2012; Granqvist, Grodal & Woolley, 2013; Grodal, Gotsopoulos & Suarez, 2015; Sarasvathy & Dew, 2005 Santos & Eisenhardt, 2009; Giarratana, 2004;
Collective action view	Long-term common goal normally aiming at social change	Activist/ volunteers	The greater good. Communal resources such as reputation, learning opportunities, control over the technology	Cultural change, change of the status quo, expression of new identity (emergence of a collective identity)	A common goal and the mobilization of resources through the activation of emotions.	Rao, 2009; Carroll & Swaminathan 2001; O'Mahony & Lakhani, 2011; Lukacs, 2000; Mezias & Kuperman, 2000; Mezias, Lant, Mezias & Miller, 2010; Spaeth, Haefliger & von Krogh, 2008
Systemic view	The creation of worth/value	Constituents of the industry (Entrepreneurs, media, educational institutions, suppliers, etc.)	Potential economic opportunities	Collective sense-making that contribute to the recognition and acceptance of the value of the new industry	Entrepreneurs' cognitive framing, ties. Other constituents of the new industry help with socio-cognitive mechanisms, distributed agency	Van de Ven & Garud, 1989; Dahlander, 2007; Navis & Glynn, 2010; Khaire & Wadhwani, 2010; Khaire, 2014

Table 2.8. 2 Case studies' characteristics

	Arduino LLC	**BeagleBoard**	**SparkFun Electronics**	**(SeeedStudio)Seeed Technologies Inc.**
Founding team	Team of 5 academics	Team of 2 working in a corporation	1 Engineer	Team of 2 Engineers
Founded	2005	2008	2003	2008
Location and reach	Switzerland & USA / global	USA / global	USA/global	China/global
Domain	Artist, designers, no engineering background	Makers, educators, explorers, professional engineers and corporations	Makers, educators, explorers, artist, professional engineers and corporations	Makers, educators, explorers, professional engineers and corporations
Licenses	Software: GNU General Public License (GPL) Hardware: Creative Commons (CC) attribution share-alike Name/Brand trademark	Software: GNU General Public License (GPL) Hardware: Creative Commons (CC) attribution share-alike Name/Brand trademark	Software: GNU General Public License (GPL) Hardware: Creative Commons (CC) attribution share-alike Name/Brand trademark	Software: X11 license (a.k.a. MIT License) compatible with the GNU GPL Hardware: Creative Commons (CC) attribution share-alike Name/Brand trademark
Ownership	Limited Liability Company (LLC)	Nonprofit	Incorporated, i.e. legally established as a corporation	Incorporated, i.e. legally established as a corporation

Table 2.8. 3 Data sources

Data Source	Quantity	Type of Data	Date collected
Archival Data	900 articles, consisting of approx. 2,800 pages	News, release reports (Factiva Database, Wired, Maker Magazines)	2014
	47	SparkFun Release reports (2009, 2010, 2011, 2012)	2014
	2	Trademark registrations (TMView database)	2014
Interviews	18 (95 double space pages)	6 founders and 12 stakeholders such as members of the maker community and OSHWA, 1 with one Fab lab manager, 1 stakeholder	2014
Websites	4	Websites from the four cases	2014
Blogs & Forums	10	Firms & founders	2014
Conferences presentations & workshops	24 presentations & 2 workshops	OSH summit	2014
	30 presentations & 1 workshop	Maker Faire Rome Italy	2014
	Induction	FabLab London UK	2015
	Course	FabLab Puebla-Mexico	2015
	Observations	Arduino Day-London, Mini-maker Faires in Torino & London	2016

Figure 2.8.1 Time line of Open Source Hardware's origins and study period

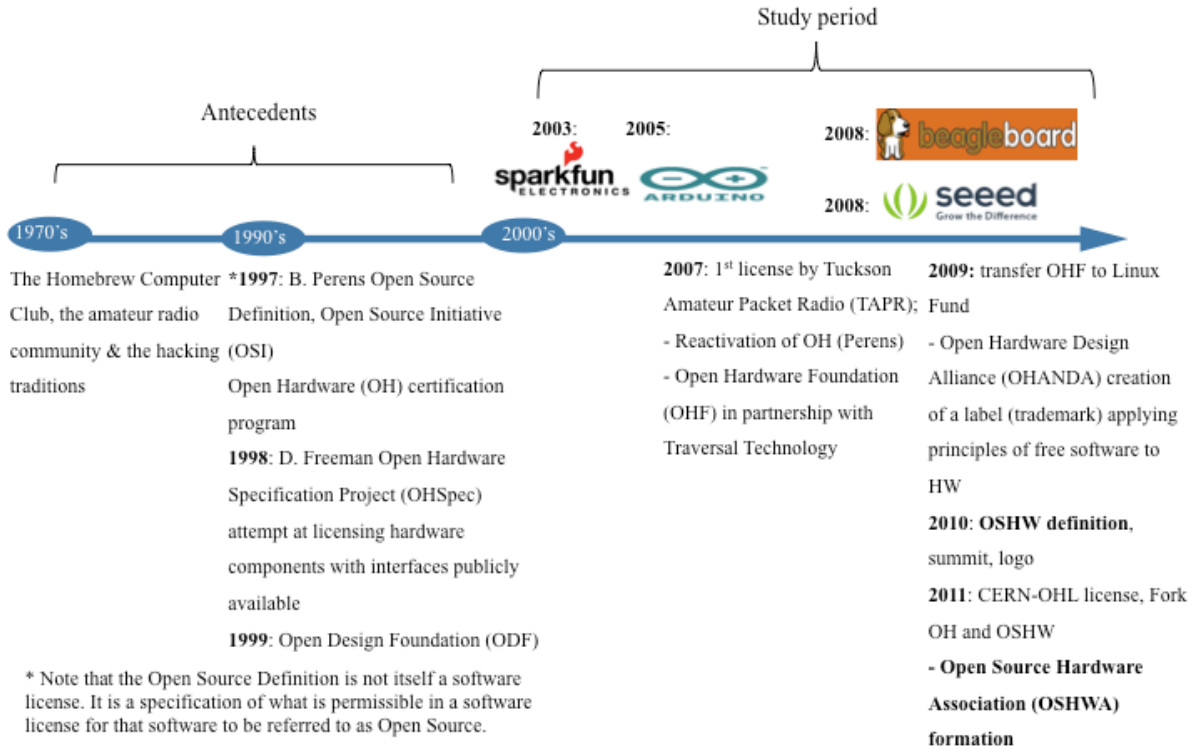


Figure 2.8.2 Number of OSHW projects/firms

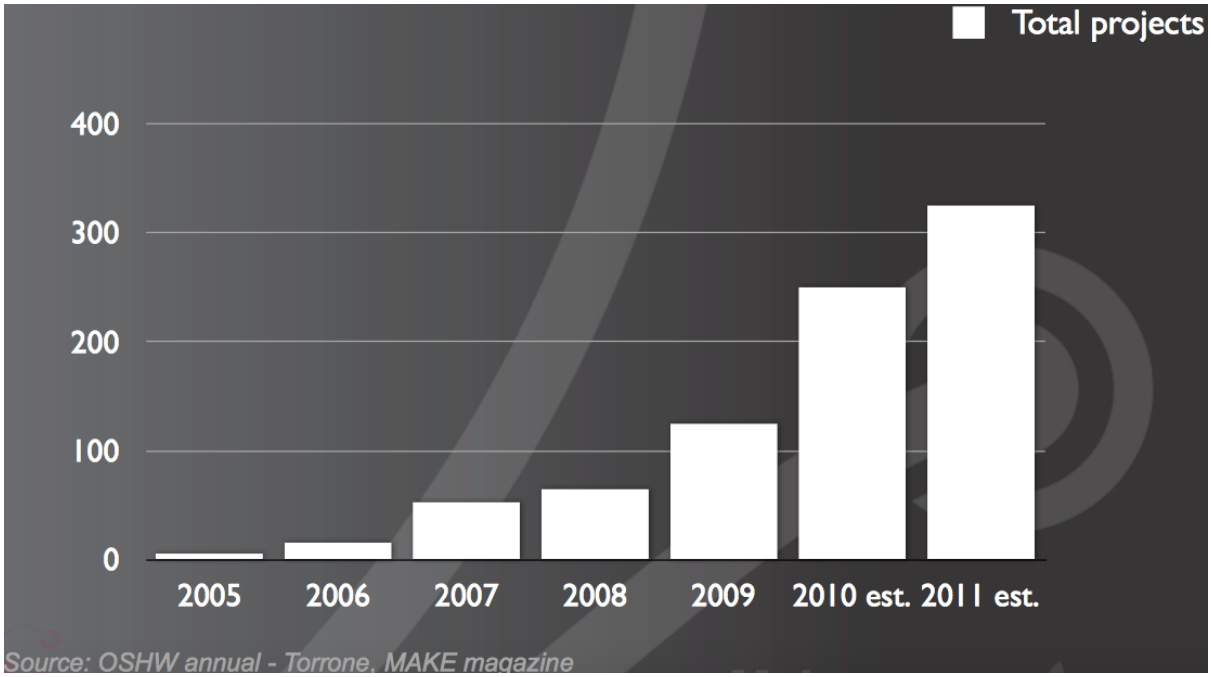


Table 2.8. 4 Cross-case comparison on clarifying products and firms

	Clarifying products				Capturing the market	
	Defining		Enticing		Convincing	
	Entrepreneur	User Community	Entrepreneur	User Community	Entrepreneur	User Community
Mechanisms	Adopt templates	The community values	Story telling	Online Blogs/forums, word of mouth	Signal leadership	Projects, Online Blogs/forums, word of mouth
Explanation	Recombination of words coming from nearby areas, familiar to audiences that facilitate understanding of complex products	Targeted users, people having a common interest in products or activities, who use & test the prototype/product	Spreading narratives about the founders and the organization	Dissemination of stories. The community creates projects with the product to illustrate what can be done with the products	Concrete actions that convey superior expertise and/or power.	Support activities that show evidence of ability and willingness to help (enthusiasm)
Arduino LLC	Open source software (OSS) & electronics, computer terminology.	New community with non-technical students (Interest in what can be done, not the technology). Involvement in the creation of logo.	Appealing message. Origins of the name and organization. Wider scope with nationality of founders.	Show & tell about the experience with products & firm, creation/ Sharing projects	Awards and achievements	Technical support, volunteer for moderation
Rating	++	++	++	++	++	++
SparkFun Electronics Inc	Online retail store & electronics, initial disassociation with the word 'open source'	Engineers but also Makers, DIY community	Charismatic leader with a funny story of the origins as start up	Show & tell with products, services, firm, creation/ Sharing projects	Appearance of being big (first fictitious and later real	Source of product/ideas
Rating	+	++	++	++	++	++
BeagleBoard.org	OSS & electronics, computer terminology & strong association with Texas Instruments	Join an established community (Linux) and create a subgroup (not sponsored) for its products	An educational non-lucrative purpose. Value for the technical expertise	List of projects posted	By association to corporations	Technical specialized support
Rating	+	+	+	+	+	+
Seeed Technology	Adoption of the new OSHW template & provider of manufacturing services	Makers, DIY community initially westerns but later Asians	Founder and origins of the organization. Use of metaphors to describe the market	Reproduce & improve cheaper prod. & collaboration with start-ups	Based on knowledge and relations	Source of product/ideas
Rating	++	+	++	++	++	++

Rating: The use of the mechanisms, a score of "+" assigned for the use of a particular action, "+ +" if a firm was particularly early and proactive in using this mechanism. An additional "+" was given for fully and active response from the community

Table 2.8. 5 Cross-case comparison on solidifying commitments

	Capturing the market		**Formalizing the market**	
	Reinforcing		**Formalizing**	
	Entrepreneur	**User Community**	**Entrepreneur**	**User Community**
Mechanisms	Emotional appeal	Online Blogs/forums, events	-External and within niche alliances, partnerships and events that give legitimization -Creation of institutions (Association)	Growth of the community, Online Blogs/forums
Explanation	Sharing more than knowledge, increases sense of belonging	Creation of a supportive culture	Establish rules, definition, standards, roles	Widespread acceptance, competition increase, new startups, appearance of copies and product derivatives
Arduino LLC	Share concerns about low income, financials, copying products, trademark violations	Active and fully responsive	Participation in the definition and creation of an association. Extensive network in other languages, training online (tutorials) & workshop (fab labs, hacker spaces), books	Groups in different regions/languages, proliferation of products with names ending in 'duino'
Rating	++	++	++	++
SparkFun Electronics Inc	Share mistakes, legal problems and gral. Community rel. events	Active and fully responsive	Participation in the definition and creation of an association	Workshops in fab labs, hacker spaces and online tutorials from company & users
Rating	++	++	++	++
BeagleBoard.org	Neutral about gral. Opinions, but share anniversary celebrations	Moderate responsive	Participation in events, donating	Products discussion in the subgroup (Linux)
Rating	+	+	+	++
Seeed Technology	Opinions on the operating culture (copying)	low responsive	Shift from reproducing external models to build internal interest and local community	The 'new shanzai' mentality, fusion of 'shanzai' culture with 'maker' culture
Rating	+	+	+	+

Rating: The use of the mechanisms, a score of "+" assigned for the use of a particular action, "+ +" if a firm was particularly early and proactive in using this mechanism. An additional "+" was given for fully and active response from the community

Figure 2.8.3 Market co-creation process – entrepreneurs-community interactions

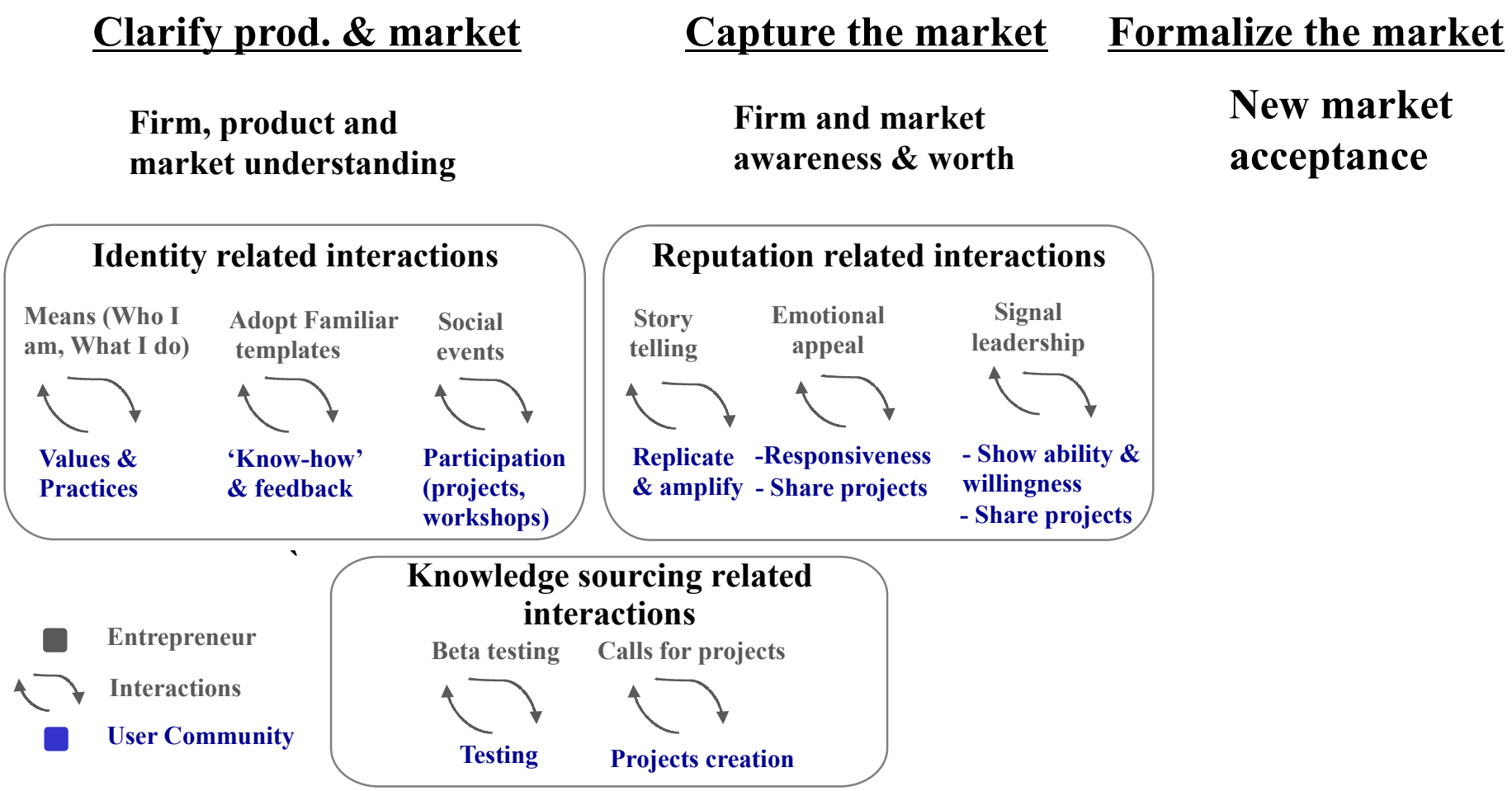


Table 2.8. 6 Description of the stages in the co-creation of a nascent market process

Focal actors	Clarifying products		Capturing the market		Formalizing
Entrepreneurs	Define product & firm - Adoption of a nearby cognitive area (Open source) as template - Previous experience	Entrepreneurs use project from the user community to clarify what the product is and how it can be used	Emotional appealing & Firm leadership	Events and extending infrastructure to cover customer demand and community growth	External and within partnerships
User Community	-The principles and common goal of the open source (use, test and give feedback) -Posting in forums the needs (attributes of products) help to define the product and target groups (e.g. artists).	Echoing stories and creating and sharing projects that use the product (help to clarify what the product is and how it can be used)	Supportive response: Members support firms engage in online activities Critique: commenting and comparing	Attract new members, the community spread to groups with other backgrounds and to non-English speaking geographical regions	Signals of formalization: - Increment of new startups, -Appearance of derivatives and clones

3. ON APPROPRIABILITY STRATEGIES FOR OPEN SOURCE HARDWARE

Abstract

Current strategies proposed in Open Innovation studies such as selective revealing apply only to firms with tight intellectual property rights. However, openness in organizations affects the selection of protection and appropriation strategies. Thus, different strategies are required for open source ventures, which face weak appropriability conditions with the free revealing of information. In addition, the emergence of organizations producing open source tangible goods, known as Open Source Hardware (OSHW) harshness the conditions since entrepreneurs have to invest to manufacture the product. I conduct a multiple case-study research with four OSHW organizations to analyze how the tangible nature of products determines their appropriation strategies. In addition, building upon the conceptualization of communities as complementary assets from Open Source Software (OSS) studies I explore how OSHW new entrants manage user communities to appropriate value. Based on the findings I outline the implications in terms of appropriation, protection and governance mechanisms.

***Keywords**: Appropriability, open source, user communities, complementary assets*

3.1. Introduction

Nowadays 'openness' is becoming much more common. Noteworthy is how open source has extended to fields outside software such as consumer electronics, automotive or communications. Organizations embracing openness from the beginning look to fill an important lack of resources for innovation. The 'openness' term is used in this article as an equivalent of free revealing, though it can also imply the involvement of external actors in the innovation process. The model followed by firms using open source is based on the creation of economic value by mining 'innovation commons' and free revealing rather than on proprietary information or technology. Among the benefits of free revealing are the enhancement of reputation, the decreasing production costs and the improvement of the innovations (Baldwin and von Hippel, 2011). However, revealing key information to external sources brings disadvantages such as the loss of knowledge (Henkel 2006; von Hippel and von Krogh, 2003), and coordination and integration costs (Dahlander and Gann, 2010).

One of the main concerns of firms is to lose the ability to appropriate returns, as Teece (1986, p. 285) pointed out "...when imitation is easy, markets don't work well, and the profits from innovation may accrue to the owners of certain complementary assets, rather than to the developers of the Intellectual Property (IP)". A review of the research of how open source firms appropriate returns indicates that in the absence of patents, firms can capture value from their innovations with a combination of alternative mechanisms such as complementary assets, lead-time advantages and secrecy (Dahlander, 2005; James, Leiblein, & Lu, 2013). Firms combine methods to balance the inefficiency of some of them, placing more emphasis on alternative methods (López and Roberts, 2002) such as hybrids of traditional value capture methods with open source (West, 2003).

Under weak appropriability conditions, i.e. when the technology is almost impossible to protect and there is risk of knowledge spillovers to competitors, firms combine appropriation methods and change appropriation strategy as they acquire more experience. For instance, new entrants that commercialize Open Source Software (OSS) try various strategies though the selling of consultancy services dominates the industry (Dahlander, 2005). Entrepreneurs choosing free revealing for their products, i.e. publishing the product design's information, require accessing complementary assets to appropriate returns from their innovation, which might be very costly and even more, they have to be careful because firms providing complementary assets could be potential imitators (Gans and Stern, 2003).

An alternative is to find means to access user communities. The creation of a community can provide first mover advantages and network externalities, reduce the learning curve and the possibility of getting free inputs for the innovation process. An example is how new entrants use community knowledge that helps firms to emerge and sell products in a new category (Haefliger, Jäger, & von Krogh, 2010). However, firms have to balance the appropriation of returns while maintaining good relationships with the community, considering it as a complementary asset (Dahlander, 2005).

This situation is problematic in the sense that cannot be acquired through the market rather it requires time to build by sponsoring employees to work with existing communities. In that way, firms try to organize/influence innovation within the community and build products and services combining internal capabilities with the work or knowledge developed by the community (Dahlander and Wallin, 2006). Another form is the creation of a new community, which a shift from 'owning' to 'managing' complementary assets for appropriating returns.

This would demand internal resources to control communities' short and long-term activities (West and O'Mahony, 2008).

Free revealing does not prevent firms to appropriate returns, but deeper insights into the phenomenon is necessary given the extension of open source to tangible objects. The change of conditions, i.e. the physicality and the increasing number of firm sponsoring communities may affect the choice of appropriation strategies. To get a better understanding on these issues, this study aims to answer the following research questions:

- How does the physical nature of open source products determine how firms capture value?
- How and when do firms use user communities as a mechanism to appropriate value?

To investigate these questions I investigate four new entrants producing and selling OSHW products. The contribution to the appropriability and Open Innovation literature is two-fold. First, the study extends the research on the means of protection and appropriation for specific industries (Dahlander, 2005; Dahlander and Walling, 2006; James et al., 2013) shedding light on the appropriation options for firms that commercialize open source tangible products. Although there is not an only way of doing things and strategies evolve over time, I propose a standard portfolio of appropriation and control mechanisms to which those ventures can relate in their forming phase.

Second, the study adds to the discussion on communities as complementary assets (Dahlander and Walling, 2006; Fosfuri, Giarratana, & Roca, 2011; Haefliger et al., 2010), by showing the different points in which firms influence sponsored users communities to participate in complementary activities such as product testing, and products support, etc. In addition, various informal governance mechanisms are implemented to control/influence community activities (Dahlander and Magnusson, 2008; Dahlander, Frederiksen, & Rullani, 2008; West and O'Mahony, 2005) and thus manage the complementary assets.

The managerial implications are that firms can pursue to manage communities as complementary assets but they have to invest resources early on to build it and not always firms succeed in getting critical mass or a responsive community. Also the implementation of a governance system that enable control and influence over external resources (partners and community) and provide the incentives for members of the community would be necessary.

3.2. Conceptual Background

3.2.1. Openness in organizations

Being open has several connotations. The literature on Open Innovation (OI) defines openness as the need to obtain ideas or knowledge from a broader collaboration outside the boundaries of the firm (Chesbrough, 2006). It is achieved through vertical, strategic alliances and peer innovation (Franke and Shah, 2003; von Hippel, 1988; West and Lakhani, 2008). Dahlander and Gann (2010) after a detailed content analysis on academic papers about OI categorize openness in dimensions of inbound (acquiring and sourcing) and outbound (selling and revealing) knowledge flows to pecuniary and non-pecuniary interactions. Strategies applied to those dimensions vary the degree of openness and their effectiveness for organizations.

Open source corresponds to the revealing dimension of openness, the free revealing of knowledge or information to the public, to gain collaboration in the development of innovations (Baldwin and von Hippel, 2011). Free revealing means granting access to product's information to all, without imposition of any direct payment to the interested agents (Harhoff, Henkel, & von Hippel, 2003). An important difference between the free revealing conception of open source and the original OI perspective is that the latter considers innovation contingent on the particular firms' business models, whereas the goal of free revealing is the cumulative production of a shared information good (e.g. software) and members coordinate their activities through informal interactions, e.g. email and development platforms (West and Lakhani, 2008).

OI stresses the value capture incorporated in the business model, enhancing profits that enable the organization to survive and grow. The ability to appropriate gains from the innovation might motivate firms to do more innovation. In contrast, in OSS the appropriation of returns is low or non-existent, shifting the capture of value to other activities (West and Gallagher, 2006b). Profiting from open source is permitted, but those who do so, should make improvements to give something back to the community.

The Open Source Hardware (OSHW) phenomenon (Raasch, Herstatt, & Balka, 2009a) shares characteristics with OSS. Nonetheless, the hardware component builds on additional challenges. Hardware products require different types of design documents and licensing, which can be divided into layers. The core practice is sharing, in this case the source files of the hardware design, in theory all the levels can be open, yet, in practice, often they are not, and the level of openness varies (Torrone, 2007). Also the model of collaboration in OSHW differs from OSS. Instead of many people working on a single project, it involves small-scale

collaborations because of 1) the investment required for prototyping, that 2) sharing components is problematic and 3) the availability of mature software tools for collaboration (Mellis and Buechley, 2012).

The decision of which appropriability strategies to follow has been linked to the openness variations discussed. The strategies' variety depends on the organization relationships with external actors, who participate in the innovation process (Laursen and Salter, 2014) and to the information being released by firms to partners or to the public. For example, firms can develop a selective revealing position, i.e. carefully selecting what and how much of the product's information is given away (Henkel, 2006, 2014). Yet, organizations choosing a free revealing approach have to take decisions regarding its operating model and reach an equilibrium that allows them to continue in existence or be viable (Baldwin and von Hippel, 2011).

3.2.2. Value capture mechanisms

According to Teece (1986, p. 285) 'a regime of appropriability refers to the environmental factors, excluding firm and market structure, that govern an innovator's ability to capture the profits generated by an innovation'. Studies on appropriability regimes have emphasized the efficacy of legal instruments of protection such as patents and copyrights. When the innovation is embedded in processes, such as chemical formulas and industrial-commercial processes (e.g. cosmetics and recipes), trade secrets are alternatives to patents; by keeping technical details unknown to the public firms derive economic value. Nevertheless, the protection of knowledge is problematic, the law narrowly defines property rights such as patents, copyrights and trade secrets, making them costly to write, monitor and enforce. In order to govern knowledge transactions a firm would require choosing mechanisms or combination of mechanisms to protect knowledge. Using too many is costly and insufficient protection lead to losses of value, thus higher levels of innovation could be observed in firms that have capabilities to resolve the innovation-protection trade-off (Liebeskind, 1996).

Consequently, to enhance organization's efficiency, it is necessary to optimize appropriability arrangements according to the circumstances, i.e. size and innovation situation (Huang, Rice, Galvin, & Martin, 2014). Research has shown the need to bundle strategies, in specific patents paired with two other strategies, secrecy and complementary assets. For example, firms that engage in both product and process innovation combine the patent approach with the secrecy method (James et al., 2013). Furthermore, hybrid strategies counteract the risk of losing the

ability to obtain returns from open strategies by combining proprietary strategies with partial openness (West, 2003) or selective revealing (Henkel, 2006). Apple's is only one of many firm that use open source, over 500 distinct components of its operating system OS X use open source components from over 180 projects, while the key elements of the user interface and the user interaction model are proprietary, which reveals a more nuanced approach of open source for strategic advantage (Lakhani et al., 2012).

In the absence of IP protection such as organizational forms with a fully revealing approach (West, 2003) or weak appropriability regime, technology is almost impossible to protect, then complementary assets plays an important role and firms have to rely on speed to market, timing and luck. In addition, informal methods such as lead-time and first mover (i.e. speed and timing) also provide competitive advantage that allows economic returns when appropriability is weak (Teece, 1986). Incumbents usually own or control complementary assets such as manufacturing capacity or distribution channels, while for start-ups access to such assets is problematic. Entrepreneurs often require engaging in strategic partnership and by having lower negotiation power, their appropriation's ability is reduced, diminishing their chances to survive (Winter, 2006). Hardware is generally patented rather than copyrighted, thus for free revealing of tangible goods the question remains about what appropriation alternatives work for ventures in such conditions.

3.2.3. User communities as complementary asset mechanisms for new entrants

A 'community' is defined as "a voluntary association of actors, typically lacking in a priori common organizational affiliation (i.e. not working for the same firm) but united by a shared instrumental goal" (West and Lakhani, 2008, p. 2). In weak appropriability environments such as OSS, the engagement of firms with communities can provide important benefits such as network effects and brand recognition. Firms support internal employees to participate in autonomous communities and their resources and expertise are combined with external resources to access capabilities that cannot be bought in the market. They use the work of the community to develop products and services and the community can help firms to commercialize the product, which fit the definition of complementary assets (Dahlander and Wallin, 2006).

Complementary assets are assets that help to successfully commercialize the product, e.g. distribution, manufacturing, etc. and could be a tangible good, IP property, and/or service,

perceivable by customers, competitors, and partners (Teece, 1986). Nevertheless, complementary assets can also be intangible resources difficult to imitate. Firms can use resources located outside firm's boundaries and in the public domain, those that engage proactively or use the effort of OSS communities, try a variety of approaches for appropriating returns, which change over time as firms acquire new knowledge and experience. The community provides inputs in the innovation process and reduces their learning curve, creating the conditions for first-mover advantages and network externalities (Dahlander, 2005).

Haefliger et al. (2010) show how new entrants apply the community knowledge in video games as a complementary asset to entry the motion picture industry and create and commercialize products in a new genre. And as the community grows firms can appropriate returns from a larger user base and create lock-ins. Although creating a community will provide more control for the firm than joining an existing community, many new communities fail because there is no adoption. Other challenges are the up-front costs, people's time to develop and engage with other members of the community, to find incentives to attract members (e.g. give away products for free) and as the products become more specialized, the base of potential followers may decrease (Dahlander and Magnusson, 2008).

Having a closer relationship with communities may facilitate contributions (West and O'Mahony, 2008). However, to access resources in sponsored community and get those benefits is a major challenge that firms face, as there is not a common way to adopt appropriation mechanisms and to align community non-pecuniary goals and values to firms' commercial interests. Therefore the study builds upon the framework for analyzing means of protection and of appropriation in OSS (Dahlander, 2005) to uncover the conditions under which entrepreneurs selling OSHW products chose appropriation mechanisms.

3.3. Research Settings and Methodology

The research settings are Open Source Hardware (OSHW) organizations, which produce and sell open source electronic products (microcontrollers). The reasons to choose these settings are in the first instance that by definition in open source organizations all the information related to the innovation is a public good (Baldwin and von Hippel, 2011) and OSHW organizations fully disclose the designs of the products. A second reason is their scope, OSHW is being applied to other industries such as automotive (e.g. Local motors) and communication (e.g. Phonebloks). Finally, the number of OSHW organizations has increased in the last decade,

some of them with revenues over USD $ 1 million (Adafruit, 2010) and large firms such as Atmel and Intel are partnering with OSHW organizations for the opportunity to seed their technology across other markets.

I followed an inductive approach with multiple case studies, recommended for situations where little is known about the phenomenon and can serve as experiments in the real world context to build theory (Eisenhardt and Graebner, 2007). The selection of the cases is based on theoretical basis. I chose two ventures, which were first to the market and two organizations late comers. The four organizations have a relationship with user communities and develop OSHW products. The firms use open source licenses (CC, GNU GPL, etc.) for their products. Finally, the organizations are still in activity with a history of at least three years, which means that they earn money from their innovations. Three ventures sponsor communities and one created a subgroup for its products in an autonomous community (Linux). The main characteristics of the organizations are shown in Table 3.7.1.

3.3.1. Data collection

The data gathering started with a search introducing the names of the companies as key words in Factiva database. The study period starts in 2003, when one of the pioneer organizations was founded, and ends in 2013, five years after the foundation of the two latecomers, which provides a comprehensive collection of publicly accessible sources of evidence for the cases. I collected archival data of the four case studies from key industry publications used include Wired and Maker magazines. The data include information from the websites of the four companies and blogs. I also searched TMView database for trademarks registrations and attended the major conferences in the field and workshops in 2014, the Open Hardware summit and Maker faire.

In all, around 900 press releases were gathered. To supplement the archival data, I conducted semi-structured interviews with 6 founders of the four organizations, and other stakeholders, Table 3.7.2 contains a summary of the sources per case. I conducted the interviews face to face, by phone, Skype and email. The interviews lasted in average one hour and the majority of them recorded with permission. The recordings were transcribed verbatim and correspond to around 95 double space pages.

3.3.2. Data analysis

First stage. The first step consisted in an iterative comparison of data from the different sources to find categories and themes until patterns in the data emerged (Boyatzis, 1998). The archival data was triangulated with information from interviews and fields notes from the participation in the conferences and workshops. The first codes are groups of quotes that maintain the experiences from the participants while induce general themes like community, protection and governance.

Second stage. The second step was to build the case studies from the material, focusing on aspects such as the history of the firm, facts and decisions in relation to appropriation. Having as references the open innovation and appropriability literature, I constructed a model with the phases of the value chain, from the development to post-commercialization activities and mapped the means of protection and appropriation, stakeholders and governance mechanisms.

Third stage. I compared and contrasted the cases, searching for cross-case patterns allowed identifying differences (Eisenhardt, 1989). I identified the appropriation and protection mechanisms employed and included governance mechanisms. New mechanisms were uncovered and I revisited data and literature to construct tables and modify the model. Table 3.7.3 presents the comparison among cases.

3.4. Findings

Organizations embracing openness require both hierarchical and collaborative processes that need to be integrated and coordinated. The appropriability orchestration involves identifying means and selecting appropriation mechanisms for activities that are critical during the invention and commercialization. The adoption of alternative mechanisms to complement the traditional hierarchical coordination requires developing governance mechanisms to gain influence and overcome the lack of authoritative control over their external collaborators.

3.4.1. The selection of appropriation mechanisms

Although there are environmental factors such as the enforcement of IP laws and the firms are geographically dispersed and subject to different institutional conditions, I focus on internal factors affecting the choice of appropriation mechanisms expressed by the founders. Free revealing eliminates the use of patents, yet it can be itself a protection. It has been used as a way to compete with proprietary software industry leaders and as an exit strategy when the product/project is not valuable anymore like the case of Netscape-Mozilla (West and Gallagher, 2006a). Table 3.7.4 shows firm's reasons for using appropriability strategies by venture.

All the cases fully reveal the information of hardware products, which give access to the drawing of the designs and the software source code on their websites or in online version control systems (e.g. GitHub or Google Code) when the product goes on sale, alternatively in a website specifically designed for sharing hardware designs, like Thingiverse. For the software, all the cases chose the usual open source software licenses such as GPL and SeeedStudio also use MIT license.

For hardware, however, copyright does not apply like in software. Usually useful or functional objects are excluded from the scope of copyright protection, but the expression of the objects in a design file may be covered by copyright. There are two types of open-source licenses: copyleft and permissive. Copyleft licenses (also known as 'share-alike' or 'viral') require derivative works to be released under the same license as the original. They include the GNU General Public License (GPL) and the Creative Commons Attribution-ShareAlike license. The CERN Open Hardware License (OHL) and the TAPR Open Hardware License (OHL) are specifically for hardware. Permissive licenses allow for proprietary (closed) derivatives; they include the FreeBSD license, the MIT license, and the Creative Commons Attribution license. The Solderpad Hardware License is a hardware-specific permissive license (OSHWA, 2015).

All the cases opted for creative commons share-alike for the hardware designs. The current state of OSHW licenses is immature and the community has not enough knowledge about how to use them.The licenses guarantee sharing and provide a kind of protection. Another popular measure is the trademark on the name and logo, SparkFun, Arduino and SeeedStudio have registered trademarks while BeagleBoard demands explicitly that people request a permission to use the name. The trademark worked as a differentiation mechanism as well, in that way organizations differentiated the product from imitators, signaling quality.

> *If somebody clones a product and doesn´t make any innovation on it, that is for me not a great idea because they are not adding anything back to the system, they are not improving the entire system as a whole. So you know, is that a threat to my business? Potentially yes, because they might be able to make it cheaper. But at the same time* ***the chances that they would be able to make it at a qualitative level are probably not as good, so that not gonna threat that way****. I think ultimately with clones what we always try to do is say to them look you can do everything you want to, what* ***we try to protect about what we do is the Arduino name, so you want to do something that looks exactly the same, great, just don´t call it an Arduino****. (Founder, Arduino)*

The firms receive licensing fees or royalties for the use of the name, which is embedded in the logo, from authorized manufactures that make the product in large scale and from distributors. An alternative way of monetization is to establish marketing programs to certify or label qualified products. Firms can capture value when other products based on original designs with innovative features called derivatives want to use the name or logo. The intention is to works similar to famous Intel Inside program in the proprietary counterparts.

Another mechanism is *Secrecy*. Timing is critical for protection in a free revealing/OSHW context, when launching a product. Organizations disclose product information and *Secrecy* is used to conceal firms' information related to a new product development. Non-disclosure agreements last for the period between the creation of the innovation and before a launch of a new product. Thereafter, the organizations disguise collaborations with other firms or individuals and the product's design information in that way they protect, at least for a period of time, their upfront investments. This is a common practice in all the cases and as one of the founders expresses free revealing does not apply to the design process.

> *To have a radically open design process, we probably should start opening up during the conceptualization phase and not just when the final object is released. But* ***in the same way that other entities decided to go for not opening their designs to their users for fear of being copied, we prefer to shortcut the IP problems by keeping things secret until the day they reach thousands of people at once****. (Founder, Arduino)*

First-mover and lead times are two strategies of ventures to keep advantages and maintain leadership. SparkFun and Arduino are the two early entrants that free reveal information and proactively developed a large user base. They gained first mover advantages; SparkFun is the largest in size and revenues and Arduino has the largest user base. Although BeagleBoard and

SeeedStudio entered later, they could compete with good technology in the products. Regarding lead times at the beginning there were not many competitors so there was not so much pressure about new product releases. Once the market started growing, the time period between the release of a product and the appearance of new products could be as short as 12 weeks (e.g. Fio-SparkFun Product). Firms realized that by combining knowledge and developing products in a faster pace provided a competitive advantage even though firms disclose the products' information at the product's launch. The following quote illustrates this approach.

> *Now imagine what it was like in the SparkFun offices the first time we saw our product (our baby) built by someone else? It was not easy. But guess what came of it? We now know we need to innovate, and do so constantly. If we can't be the best at something, we'd better get the heck out of the way.* ***Intellectual property allows for some protection, albeit at a legal expense****. On top of that, IP holders can be tempted to sit on their laurels and in this day and age, that can be the kiss of death.* ***We use open source hardware as a way to stay sharp****. (CEO & Founder, SparkFun)*

On the other hand, all the actors participating in the value chain to produce and commercialize the invention are important. The findings suggest that firms formed strategic *partnerships* that provide manufacturing and distribution services, something that new entrants often lack. The challenge for the cases in their early stages was to find strategic partnerships, to convince partners about profits or innovation incentives especially for production of batches (small size) and distribution in different geographies that allows customers to buy the products.

As the firms grew, some of them built internal capabilities to manufacture the hardware components. However, strategic partnership was necessary for a global reach and support activities such as testing new products. Only one case (Arduino) built in-house manufacturing and still did some partnership with SparkFun to manufacture in USA. While the non-profit BeagleBoard, which is the smallest in terms of employees, sought partnerships though faced some distribution limitations. Nevertheless, the financial incentives for partners were in place as the following quote documents.

> *The revenues on board sales are in excess of $1 million annually and continue to rise, but the business model here is one of enabling the technology partners, not making money off the board sales. That said,* ***all parties in the value chain are making money***

> ***off the board sales****—and this helps to keep the ecosystem alive where people can participate at almost any level. (Founder, BeagleBoard)*

The limitations of obtaining returns from designs obliged firms to find other means of obtaining revenues. The provision of *Services* is a common alternative to earn revenues from firms' expertise and around the products such as consultancy services, training or support to larger organizations or even to the same market as the case of SparkFun and Seeed Studio, which positioned itself as manufacturing service providers of the new market.

For Seeed Studio, services are the main source of revenues, given the expertise in the Chinese manufacturing network. The cost and flexibility of the small scale in the quantity of manufacturing goods give Seeed an edge in the production of OSHW products for the community over other firms. While SparkFun use manufacturing services mostly partnering with projects coming from the crowdsourcing platform Kickstarter. Their approach is also known as Manufacturing as a Service (MAAS) and specialized in small batch production.

> *I loved the openness, creativity and huge energy of this community and* ***so I started to provide makers with open source products and modules plus services*** *to help them create their products. (CEO & Founder SeeedStudio)*

3.4.2. Access to community resources

The organizations targeted a niche market. Arduino and SparkFun sponsor communities whereas BeagleBoard engages with an autonomous community and Seeed studio connect to the existing ones doing OSHW. Some communities are more participative, which it is related to the type of relationship that firms develop and how well they motivate the engagement of members. Table 3.7.5 presents illustrative quotes by venture regarding community activities that support the notion complementary asset.

The firms built products taking into account the contributions of community members in forums or from direct interactions with user in workshops and the engagement with a community provided capabilities for the improvement of the product and support activities by monitoring problems and requirements.

> *TI really keeps beagleboard.org separate from corporate TI. We got* ***a tremendous amount of guidance from the community about developing the product****. (Founder, BeagleBoard)*

A second incursion of the user community in the product development is the support during the launching of the product, doing beta testing with new products and provide services such as give support to other members, which help to improve the quality of the product and consequently its commercialization. The composition of sponsored communities might influence the community contributions but despite the differences one common characteristic is that users do support in the companies' websites forums.

Other indirect activities of the community that happen in an ongoing basis are promotion and monitoring. Members of the community spot imitators than infringe trademark rights and volunteer to be moderators depending on the language/country, which is a valuable source of skills and resources. In addition, firms use the work of the community in other projects in consultancy services. The community was also a source of information about future market potential, which is important to support first mover and lead time strategies. And the community can become a differentiation mechanism, Arduino founder illustrates how the formation of a base of customers that are perceived as valuable.

> *Banzi heard one story about Intel unsuccessfully trying to sell a customer a new processor. "The customer told them, '****I'm not moving even if you give me the processor for free because I don't want to lose the community****,'" Banzi said. "For this person, it was very important to have a platform based on Arduino and the Arduino community behind it." (CEO & Founder, Arduino)*

In sum, firms chose appropriation methods such as secrecy to protect their innovations for a short period of time, during the development process until the launch of the product. All the cases use creative commons share alike (cc) as open source licenses for the hardware components of the products. The selling of services remains a source of economics returns for firms disclosing both the software and the design of their products, but there is novelty in firms' incursion in manufacturing as a service.

3.4.3. Governance mechanisms implemented by OSHW ventures

New entrants faced particularly high uncertainty about the market demand and the adoption of technology. Teaming up with the user community to work on the products helped to generate interest. Although awareness is important, firms needed to channel the enthusiasm of the community while maintaining the members' freedom to participate. The data show that the firms implemented three governance mechanisms that address the interaction with the community while retaining the direction of the organization: 1) Benevolent dictator, 2) Contests and 3) Reward system. Additionally, to work in partnerships firms employed the traditional 4) Contract mechanism. Table 3.7.6 presents illustrative quotes by venture regarding community governance mechanisms.

Benevolent Dictator. All the cases were able to attract the interest of people not only in buying products but also in becoming part of the firm's user community. The figure of a 'benevolent dictator' is one of the governance mechanisms in OSS; the founder of an open source project has the decision-power on the most important issues regarding the project (O'Mahony and Ferraro, 2007; Raymond, 1998). OSHW ventures sponsoring communities have to deal with matters of ownership, diplomacy and technical expertise. Effectiveness and feedback impact decisions and although it is not possible to keep everybody happy, ventures learn to harness knowledge from the community without alienating most of its members.

> *"**When it comes to BeagleBoard designs, ultimately Gerald is the designer, he has the final say, but he listens to the inputs from the community and it is kind of a benevolent dictatorship** in that way, but in the other ways we allow everybody to come in and speak to in the emailing list, register the messages in the web site, get the message out." (Founder, BeagleBoard)*

The features of a 'benevolent dictator' model suggest the definition of 'roles and responsibilities'. The benevolent dictator did not become symbolic over the time, even if there is firms' employees' rotation, the organizations retain the decision power. Users are given roles as moderators of the forum, collaborators of projects or contributions as developers. Credits are demanded and given. Users perform activities with limited authority such as eliminating spam from the forum and support to specific area of expertise or language.

Contests. Tools like polls or surveys to ask the community about features of products are complemented with the use of contests, which is a periodic event launched by the firms, in

which employees and public compete but the commitment to specific dates are set and a mix of intrinsic and extrinsic rewards are involved. With the increase of new entrants, the pressure to release new products is higher, thus the pace of the product development increase. The contests such a hackathons apart from forming bonds with the community or employees, depending on who is involved, provide a fast dynamic way to test products with immediate feedback. As Seeed Studio expressed in its website '*we should try out our products in depth to keep them evolving in the right direction*'. At the same time, the release of products in the market might not reach customers and the firm used contests to create awareness, SparkFun costume contest and Seeed Studio illustrate the promotion side of contests.

> '*So we recommended him to use Xadow, but he said he has no idea there is such a thing.* ***This inspired us to initiate a contest to collect interesting, creative and excellent recipes*** *made with Xadow to bring it out of shadow this summer, so that more makers get to know that when the project comes with a wearable purpose or space-sensitive design, Xadow might be a good choice for them' (Seeed Studio Blog).*

All the cases stressed the bonding of the community and the learning benefits, gaining a growing number of participants. Some contests or events such as Maker Faire can become an iconic events. Designing contests entangle the building of capabilities with governance. The contest-organizers provide the criteria for winning the competition, with firms usually retaining the control over external collaborators and steering the direction of the innovation.

> *"BeagleBone Cape Contest Official Rules*
>
> *For purposes of these Rules, "TI" shall mean Texas Instruments Incorporated and its subsidiaries and "Circuitco" shall mean Circuitco Electronics LLC and its subsidiaries. TI and Circuitco are collectively referred to herein as the "Sponsors."...PARTICIPANTS DO NOT RECEIVE BY WAY OF OR UNDER THE CONTEST ANY INTELLECTUAL PROPERTY RIGHTS IN ANY COPYRIGHTS, PATENTS, TRADEMARKS, TRADE NAMES, TECHNOLOGY, TRADE SECRETS, OR KNOW-HOW OF THE SPONSORS OR ANY THIRD PARTY." (BeagleBoard)*

The firms provide prizes that may fulfill the extrinsic motivations and the atmosphere and reputation earned by winning the contests add to the intrinsic motivation to participate.

Reward system. Early entrants gained popularity and prestige, attracting attention and collaboration. Late entrants such as Seeed Studio were competing for people's time to provide

support to fellow members in the forums or to post projects. To address the lack of resources to monitor the forums and motivate participants, Seeed implemented a reward system to encourage participation in the forum while its employees keep the moderation activities. As the competition increases with the proliferation of other OSHW projects asking for the time of collaborators, an incentive structure supplements the reputation gained. The reward system involves getting public credits and other intrinsic incentives combined with extrinsic incentives such as getting freebies.

> *Points system. This is a unique feature of our forum. Points are reflecting your contributions on forum. We are work together on build technical forum for all Seeed's friends. Those points are available to redeem in "Point Redemption Area", you will get some samples or products for free. (SeeedStudio)*

Contracts. Contracts and Non-Disclosure Agreements (NDAs) are governance mechanisms that remain essential instruments to achieve first mover and lead time advantages when working in the development of new products. When working with other firms, the efficiency perspective on minimisation of governance cost and avoidance of individual opportunism through the use of legal contracts still apply. However, there are also implications in the collaboration of OSHW ventures with firms that work under the tight appropriability regimes, i.e. using patents. In the contracts, collaborators agree to work on products that will be released under open source licenses and figure out how and to what extend proprietary components can be integrated with OSHW products.

To sum up, firms followed a centralized approach with sponsored communities. The dominant 'benevolent dictator' model simplified the decision making in terms of incorporation of improvements and conflict resolution though with the help of external moderators. Yet firms experimented with governance mechanisms such as the reward system, which are not mutually exclusive, mechanisms directed to find the best way to work in the firm's platform in which the community members interact.

3.5. Discussion

Value appropriation is a special concern for firms that choose openness (Laursen and Salter, 2014). And previous research on appropriation in OSS contexts advises that firms creating and

selling open source products should pursue a hybrid strategy with both proprietary and open source methods, e.g. developers have used free software to sell hardware, other proprietary software or services such as consulting, support and training, which are assets complementary to the free software created (West, 2003) or selectively reveal information (Henkel, 2006). However, this study provides a more granular view for appropriation strategies in open source (Dahlander, 2005; Dahlander and Wallin, 2006) by proposing a standard portfolio of mechanisms for OSHW firms, shown in Figure 3.7.1. The combination of the physical nature of the products with free revealing affects the following elements in the appropriation strategy: 1) licensing mechanisms for OSHW, 2) the composition of sources of revenue and 3) the user community as complementary assets. I explain next these three elements, the rest of the mechanisms were described already in the findings.

The first implication is on the licensing mechanisms. OSHW ventures follow similar patterns than OSS ventures, since the products have the software component, firms select and combine legal instruments with non-formal methods such as releasing code with OSS licenses and releasing it early to get a large amount of users (Dahlander, 2005) and use the current OSS licenses (GNU Public License (GPL) and Massachusetts Institute of Technology License (MIT) for the software in their products. Licenses for hardware are still in development and likely to change as people experience with them. There are licenses that cover firmware, or drawings but there are characteristics in hardware that are not yet covered, e.g. derivative work.

Basically everybody by themselves or producing with a third party can use, copy and make derivative work with products under open source licenses, if they have the materials and tools available (Balka, Raasch, & Herstatt, 2010; West and O'Mahony, 2008). All the cases adopted the Creative Commons (CC) "share alike" that covers copyrighted works over schematics and/or drawings of the design. There are not yet legal cases that show how effective the new licenses are in terms of dispute resolution.

The second implication on firms' strategy for appropriation is the composition of sources of revenues. Firms' attention shifts to trademarks on the name and logo as means of protection, as well as the use of trade secrets before product's launches. Trademarks and brand licensing are a source of financial returns and one important protection mechanism against derivatives and clones, i.e. products of similar or identical design from different producers (Mellis, 2014). Two cases had incidents with trademarks, SparkFun with a corporation about its name, the

founder appealed to the users to support the firm in this event. Arduino with an internal dispute between founders for the name of the firm. The firm have to change the name of the product in Italy and the appearance of a new website with the name Arduino.org cause confusion among followers and even distributors and manufactures had to take side, though difficult to identify the impact on revenues, many users comments indicate that many users had to identify which Arduino to buy.

In addition, since products have to be manufactured, the services that ventures provide are extended to this field. Traditionally, services are based on the transfer of knowledge providing workshops to people, teaching other firms' employees and consultancy, which still apply. A new modality is to do manufacturing as a service, to manufacture small batches of products of other firms or individuals.

The user community as complementary asset

Dahlander and Wallin (2006) introduced the notion of user communities as complementary assets, which provide services for and representing the firms. To achieve this, firms assign employees to work with autonomous communities to try to influence the community direction and get community knowledge. This seems to be the case of BeagleBoard with TI, although the founders mention that it was a personal initiative and the firm donated their time to work in the Foundation created a subgroup in Linux community that support BeagleBoard products. The other approach is to sponsor communities; scholars found that the idiosyncratic relationships between firms and sponsored communities are intangible assets and sources of potential competitive advantage (Fosfuri et al., 2011; Haefliger et al., 2010).

This research complements those grounding studies by focusing on sponsored communities and new entrants in the OSHW emerging market by showing how and when the firm-community relationship contribute to the appropriation of value. Communities can support the commercialization of the product during the product development, with inputs and feedback for the product. It's hard to predict what people will need, and the community has been valuable to choose directions aimed to have good commercialization. It also has been valuable not only in the dissemination and adoption of technology but also in marketing activities (Dahlander and Magnusson, 2008), for instance the diffusion of the innovation in online tools (Blogs, forums, social media).

Although firms do not 'own' community resources and community members do many activities in a voluntary basis, firms have closer interactions with them and have to find ways

to ‘manage’ community’s activities and smooth the differences in goals (West and O’Mahony, 2008). The values of open source communities provide the ideological mechanism of integration and the interaction tools can serve as means of subtle control (Dahlander and Magnusson, 2005), yet governance mechanisms are required to prevent the formation of a dominant interest (O’Mahony, 2005).

Given the close relationship of firms with user/open source communities, one of the challenges for the firms is how to use communities when they have limited control and in the community there are different levels of capabilities and diverse degree of involvement. Firms then have to establish governance structures that include mechanisms to manage user communities (Dahlander et al., 2008). The governance figure of the ‘benevolent dictator’ is one of the mechanisms identified in sponsored communities. Firms have to take decisions about incorporate contributions and resolve conflicts. This approach establishes a centralized model taken from OSS communities; the founder of the project/firm is the one who do all the decision-making, an autocratic leader (O’Mahony and Ferraro, 2007). In addition, the firm gives community members the opportunity to take more responsibilities (West and O’Mahony, 2008) in activities of community management, as moderators in forums based on geography or expertise rather than leading the decisions in product development, which differ from findings in (Dahlander and Magnusson, 2008).

Short-term activities such as contests have two purposes: to encourage innovation and to stimulate the social interaction to attract interest to products/firms. Firms establish rules of contests, the IP rights and define the direction of the innovation. For OSHW ventures, the call for contests is a mechanism to influence the community. Contests can become a symbol, a ritual supplied by the firm to build a community focused strategies that can lead to product differentiation (Dahlander et al., 2008; Fosfuri et al., 2011).

3.6. Conclusion

The study adds to the discussion of contexts under weak appropriability regimes, particularly open source (Dahlander, 2007). The relation of openness and appropriability strategies is an issue relevant for management (Laursen and Salter, 2014). In the emergence of organizations producing open source tangible products, I outlined the challenges they face and the implications on the composition of the appropriability portfolio. Entrepreneurs have the

illusion that developing new products that fulfill customers' needs guarantee success. However, under weak appropriability conditions complementary assets become relevant (Teece, 1986).

The user communities as complementary assets (Dahlander and Walling, 2006; Fosfuri et al., 2011; Haefliger et al., 2010) can be the means to do complementary activities at the beginning and end stages of the product development cycle that facilitate commercialization of products. As well as get information from users that would expand new knowledge domains for the use of their products, giving new paths for the commercialization of it. However, the attraction of external collaborators needs collaborative ways with flexible governance mechanisms to coordinate community activities (Dahlander et al., 2008) on the daily basis and in short-term activities such as contests.

The managerial implications are that firms can pursue to manage communities as complementary assets but they have to invest resources early on to build it and not always firms succeed in getting critical mass or a responsive community. Second, managers have to establish a governance system that enable control and influence over external resources (partners and community) and provide the incentives for members of the community.

Limitations and future work

As with any study conducted in a single industry further work would be necessary to extend the generalizability of the findings. As open source spread to other industries like automotive, medical devices and telecommunication, there would be more firms to include in the sample of future research. Similarly, the sample of the study comprises only new entrants; it would worth to investigate how the portfolio of appropriation mechanisms would be affected when collaboration with incumbents that have patents increases.

Regarding the community as a complementary asset, more research is required to validate to what extend the findings can be applied to entrepreneurial ventures with a tight appropriability regime. And determine differences with industries that benefit from contributions from community members such as toys, entertainment, medical devices, manufacturing, sporting goods, music (Franke and Shah, 2003; Jeppesen and Frederiksen, 2006; von Hippel, 2005) and with firm that engage with communities that affect their core innovation (e.g. Threadless, Quirky).

Finally, an avenue for future research is how to maintain the interest of the community. Members' participation could decrease when their personal or professional projects have been done. Also larger communities represent a bigger challenge to manage, firms would require more resources. Another unanswered question is how effective current governance mechanisms would be for larger communities and it is an issue of incentives as well, how firm can keep existing members and attract new participants to avoid a depreciation of the asset.

3.7. Tables & Figures

Table 3.7. 1 Case studies characteristics

	Arduino	BeagleBoard	SparkFun	SeeedStudio
Founding team	5 members, the majority are academics	2 members, working at TI corporation	1 Engineer	2 members, Engineers
Founded	2005	2008	2003	2008
Location and reach	Switzerland & USA / global	USA / global	USA/global	China/global
Domain	Artist, designers, no engineering background	Makers, educators, explorers, professional engineers and corporations	Makers, educators, explorers, professional engineers and corporations	Makers, educators, explorers, professional engineers and corporations
Licenses	Software: GNU General Public License (GPL) Hardware: Creative Commons (CC) attribution share-alike Name/Brand trademark	Software: GNU General Public License (GPL) Hardware: Creative Commons (CC) attribution share-alike Name/Brand trademark	Software: GNU General Public License (GPL) Hardware: Creative Commons (CC) attribution share-alike Name/Brand trademark	Software: GNU General Public License (GPL) Hardware: Creative Commons (CC) attribution share-alike Name/Brand trademark
Ownership	Limited Liability Company (LLC)	Non profit	Incorporated, i.e. legally established as a corporation	Incorporated, i.e. legally established as a corporation

Table 3.7. 2 Data sources

	Arduino	BeagleBoard	SparkFun	SeeedStudio
Articles	760	111	85	14
Website	1	1	1	1
Blogs	4	1	1	1
Interviews (Founders)	2	2	1	1
Press releases			47	

Other Sources		
Interviews	Users	11
	Founder of OSHWA association	1
Conferences	OSH summit	24 presentations & 2 workshops
	Maker Faire	30 presentations & 1 workshop

Table 3.7. 3 Comparison of appropriation and governance mechanisms

	Description	Arduino	BeagleBoard	SparkFun	Seeed Studio
Means of Protection					
Copyrights	Name & logo	X	X	X	X
Secrecy	NDA	X	X	X	X
Lead time		X		X	
Complementary assets					
Manufacturing		Partial ownership	Partnership	Ownership	Suppliers
Distribution		Partnership	Partnership	Partnership	Partnership
Community		X	X	X	X
Additional revenue streams					
Services	Consulting, training, support	X		X	
Other	Online consumer electronics retail or Manufacturing broker	X	Donation. Paid by TI as employees	X	X
Governance mechanisms					
Product innovation	Incremental innovation, contests	Hierarchy/Benevolent Dictator	Benevolent Dictator	Inside Team vote	Hierarchy/voting system
Forum	Support	Designated members of the community (based on meritocracy)	Mainly internal members	Mainly internal members	Mainly internal members/ Reward system

Table 3.7. 4 Representative quotes of the reasons for using Protection mechanisms

Organization	Protection Mechanism	Founder Rationale	Illustrative quotes
Arduino	Trademark	Identity	… the hardware is released as Creative Commons, the software is released in the GPL license and LGPL license, the documentation is also Creative Commons, only the brand Arduino is trademark ***to make sure that we can actually, you know, clearly say this is what we are doin***g, and if you want you can buy your board made by somebody else, you know, its perfectly natural it's important to have multiple ways of getting your hands on technology, but then ***we wanted to clarify who we are*** and and what we sort of to contribute in a way, and it really became a tool that idea that it's open, encourages sharing it becomes a tool for innovation...
		Efficiency (cost)	there's a practical level why we retain the trademark. ***The hardware end of the business is commercially self-sustaining, but the software doesn't pay for itself***. We charge a license fee to the licensed manufacturers for each board they sell. That money goes to pay for maintenance and development of the software and the website. It allows each of us to take a couple hours a week off from our other jobs to maintain the parts of the Arduino system that don't pay for themselves. You can make derivatives works without permission, ***it's just the name that is trademarked***.
		Reputation and quality	***We registered the trademark. It's pretty common to do that in open source***. If you look at Linux, MySQL, or Apache, or Ubuntu, for example, they're all trademarked, even though they are open source. So those were our models. There are a couple reasons why we chose to do this. First off, names carry responsibility. While we're happy with people using the design files or the code we've generated, ***we feel that naming is something that should remain unique***. When a person buys an Arduino board, she should be able to count on the manufacturer standing behind it. We do, for those manufacturers to whom ***we've licensed the name because we work closely with them to ensure a standard of quality*** and ease of use that we are proud of. If, on the other hand, someone buys a board called Arduino from a manufacturer with whom we have no contact, and then sends it to us or to one of our manufacturers for repair or replacement, we (or they) can't be expected to service it. We can't guarantee the level of quality with someone we haven't been working with.

Table 3.7.4 (continued)

Organization	Protection Mechanism	Founder Rationale	Illustrative quotes
BeagleBoard		Normative	The design is what is provided and covered by the open source license. If you want to copy the headers and form factor and make it based on say an Atom processor, knock yourself out. Just ***make sure you give full credit to your version to the designer of the original board and put the design back into open source such that everyone can copy your design as well.*** Nothing has been done to patent/trademark/etc. the pinout and TI would not come after you. It would be great to have other hardware that can make use of http://beagleboard.org/capes. ***We wouldn't like it if you used the BeagleBoard.org, BeagleBoard or BeagleBone names as a definition of your product, but, as you say, you can say you've created a "BeagleBone cape", "XYZ cape" or board with a "BeagleBone-compatible header"***. You've got the point right that the difference is declaring your board to work with BeagleBone vs. saying it *is* a BeagleBone.
Arduino	Secrecy	Protection	To have a radically open design process, we probably should start opening up during the conceptualization phase and not just when the final object is released. But in the same way that other entities decided to go for not opening their designs to their users for fear of being copied, ***we prefer to shortcut the IP problems by keeping things secret until the day they reach thousands of people at once***.
SparkFun	Lead time	Speed as competitive advantage	The secret of open source is innovation. ***If your company cannot innovate quickly, it will lose to the competition***…Behind every open source company, you will find people innovating quickly and freely. ***Open source entrepreneurs make money quite simply because they are innovating faster***

Table 3.7. 5 Community activities that support the notion of complementary asset

Organization	Value added activity	Illustrative quotes
Arduino	Design collaboration	We operate at two different levels, one of them is all our products are open, the second one is we have an open process in the essence that we listen to people, ***we collaborate with them, and we try to accommodate to their needs*** as long as we fulfill some basic principles on making general devices that can be used by as many people as possible.
	Documentation	...So we need to give them the documentation for free and allow them hack that documentation and reuse it and improve it, we were at the beginning just five people, so we said let, you know what, everything is Creative Commons and GPL so take it improve it and if you want to pay us back by putting on our website you have this website open here just put bunch of things, you know, that ***the biggest repository in Arduino documentation is the Arduino website, made by a hundred and twenty thousand registered users, that's it, you know and we have changed the way companies that produce silicon create documentation about their products they don´t make it with the company members they make it with a community of users***
	Testing	After buying the board you'll receive an invitation to join the beta-testing program, ***as a beta-tester you will be able to contribute to the development of the board by signing up for tasks and projects***. You'll be working alongside the Arduino and BeagleBoard.org teams on tasks such as writing examples, testing libraries and external hardware, and making projects. Completed tasks will be rewarded with a special program of benefits, including the possibility of featuring your project on the Arduino blog and receiving a coupon for the same value of the TRE Developer Edition you purchased. We will be beta-testing the board for about three months.
	Product Development	If you peel back the surface, ***underneath Arduino project you can find a lot of collaboration***. On one side you can see a selection of pretty amazing ***open source software contributing to what Arduino has become***. I'm talking about GCC, processing, wiring, AVR, and all the other contributions from the community. On the other side, I started to involve specific people… All the founders brought their own experience into Arduino and ***later what became really important was the Arduino community***. At the moment there is a community much larger than number of official Arduino boards we have sold. There are more than 180,000 people subscribed to the forum and more than 4 million monthly page views to the website with visitors spending about five minutes on each visit.

Table 3.7.5 (continued)

Organization	Value added activity	Illustrative quotes
BeagleBoard	Support	These design materials are *NOT SUPPORTED* and DO NOT constitute a reference design. ***Only "community" support is allowed*** via resources at BeagleBoard.org/discuss.
	Product development	-*When it comes to BeagleBoard designs, ultimately Gerald is the designer, he has the final say*, **but he listens to the inputs from the community**. -*TI really keeps beagleboard.org separate from corporate TI. We got* ***a tremendous amount of guidance from the community about developing the product****. (Founder, BeagleBoard)*
SparkFun	Access to skills	I believe there's a way that we can say hey I need this thing built, I need this thing to tinker it, would you please help me we need some sort of peer to peer network that allows us to sort of help sign folks up because they got some free time they've got the skills. We actually saw this ***we had a soldering competition*** in Boulder Colorado right we just said hey we're going to do this thing up, fifty competitor showed up they even brought their own Net Cal's. ***We thought we were going to get some like amateur shown up***...these guys were fast and they were serious and it just goes to show even in a small community like Boulder Colorado or Longmont Colorado ***these are folks that are ready to assemble stuff right they've got the skills and imagine if they have the ability to sell sort of their services these are experts in the field***
	Product development	We received a ton of new insights and actionable suggestions as we spent up to an hour with customers on the phone. Some ideas we had already considered, but as a result of the feedback, we pushed them up the pipeline.
SeeedStudio	Marketing	***Seeed Studio has so far depends on words of mouth of open hardware community for its marketing*** and will launch its first marketing campaign in 2011. The following is one of the first ads to be run in Make Magazine. Seeed also works with partners' sites such as Dangerous Prototypes to promote the platform. (Xinshanzhai [1]: Seeed Studio and Facilitate Open Innovation, 2010)

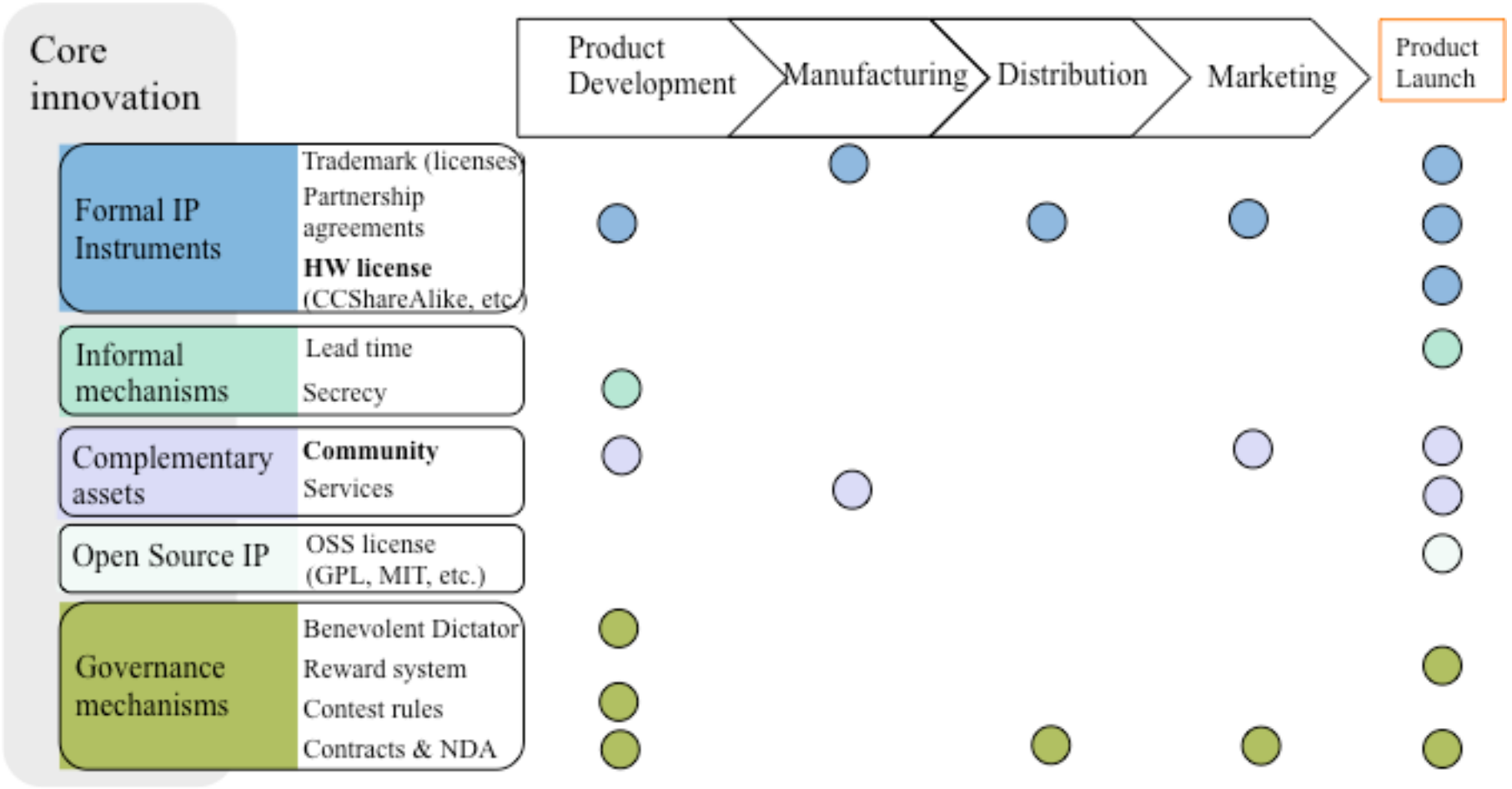
Table 3.7. 6 Representative quotes for community governance

	Arduino	BeagleBoard	SparkFun	SeeedStudio
Benevolent Dictator	"… it's sometimes hard to have a completely open process all the time, it is hard to have a lot of opinions, it's hard to filter all these opinions to make something that is meaningful and generalizable enough so that people can use it, so ***you need always someone to act as the benevolent dictator***..." (Founder, Arduino)	***"When it comes to BeagleBoard designs, ultimately Gerald is the designer, he has the final say***, but he listens to the inputs from the community and it is kind of a benevolent dictatorship in that way, but in the other ways we allow everybody to come in and speak to in the emailing list, register the messages in the web site, get the message out." (Founder, BeagleBoard)	"Leadership and management? ***We are a fairly normal 'benevolent dictator' type organization***. There's me, then 8 directors who help me run the company" (CEO founder, SparkFun,)	***The Judge prize will be chosen by our benevolent dictators*** in allowance with the rules. Or, break the rules and go for the Jury prize selected by your peers instead!
Contest Rules	Arduino redesign competition. You have until midnight of the 28 of October 2005 to send us a redesigned version of the website. Since there is only 1 template you just need to send us the redesign of the homepage. ***The jury composed of the arduino team will pick the entry that we like the most*** and will award the winner with 3 pre-assembled Arduino boards + 10 blank Arduino serial boards. If you are feeling generous and want to propose a logo as part of the redesign please do so.	BeagleBone Cape Contest Official Rules ...***PARTICIPANTS DO NOT RECEIVE BY WAY OF OR UNDER THE CONTEST ANY INTELLECTUAL PROPERTY RIGHTS IN ANY COPYRIGHTS, PATENTS, TRADEMARKS***, TRADE NAMES, TECHNOLOGY, TRADE SECRETS, OR KNOW-HOW OF THE SPONSORS OR ANY THIRD PARTY." (BeagleBoard)	Being the first Autonomous Vehicle Competition (AVC) ever (2009) this event ***was highly experimental. Nobody really knew what to expect. Much was learned by staff and competitors alike***. Many competitors returned in 2010 armed with knowledge and experience.	DSO QUAD competition Special Declaration...4、All entries will be taken as open source products, win or not, the entries are accessible to everyone; 5、***All rights are reserved by the event organizer***

Table 3.7.6 (continued)

	Arduino	**BeagleBoard**	**SparkFun**	**SeeedStudio**
Reward system	The original intention of the Arduino project was to see what would happen if community support were substituted for the corporate support that is usually required for electronics development. The first developers — Massimo Banzi, David Cuartielles, David Mellis, and Nicholas Zambetti — ***ran a series of workshops on assembling the Arduino, giving away the board to stimulate development***	… You'll be working alongside the Arduino and BeagleBoard.org teams on tasks such as writing examples, testing libraries and external hardware, and making projects. ***Completed tasks will be rewarded with a special program of benefits***, including the possibility of featuring your project on the Arduino blog and receiving a coupon for the same value of the TRE Developer Edition you purchased. We will be beta-testing the board for about three months.	SparkFun Free Day, a day unto which the distributor from Boulder, CO ***decides to give away rewards to its customers in order to show appreciation and support. For each person that logged in or created an account***, they got the opportunity to spend up to $100 of in-store credit on anything in SparkFun's store by answering technical trivia while they were shopping.	Points system. This is a unique feature of our forum. ***Points are reflecting your contributions on forum***. We are work together on build technical forum for all Seeed's friends. Those points are available to redeem in "Point Redemption Area", ***you will get some samples or products for free***. (SeeedStudio)

Figure 3.7.1 Protection, appropriation and governance mechanisms in OSHW



4. CRAFTING PHYSICAL SPACES IN OPEN INNOVATION ENVIRONMENTS

Abstract

Research and Development (R&D) labs have been instrumental in the development of firm's internal innovation. With the rise of the Open Innovation paradigm, firms are implementing new strategies to source ideas outside their boundaries with the help of Internet platforms and with new forms of organizing in alternative spaces, e.g. sponsoring/partnering makerspaces to reach out external collaborators. Yet little is known on physical spaces supporting firms' external collaboration. To address this, I conduct a qualitative case study research using the spatial liminality concept, which theoretically can spark creativity and induce behavior. Drawing upon the findings of a comparative analysis of three spaces: A headquarters, a living lab and a sponsored makerspace, and their liminal dimensions, I developed a conceptual model with the elements to craft innovative environments. The study provides empirical evidence and develops the argument that the levels of spatial dimensions influence the type of visitors and interactions happening in the space, which ultimately induce innovative behavior. Additionally, the study outlines trade-offs in the crafting of liminal dimensions, which can provide guidance for managers and policy makers on the establishment of innovative spaces.

***Keywords**: open innovation, communities, collaboration spaces, liminality*

4.1. Introduction

Physical spaces impact organizational processes, e.g. they affect communication (Allen, 1997), concentration (Banbury and Berry, 1998) and collaboration between individuals (Kabo, Cotton-Nesslerf, Hwang, Levenstein, & Owen-Smith, 2014). Regarding the use of spaces to support innovation, many organizations, e.g. the Royal Mail create dedicated spaces (labs) to support creativity and innovative behavior, to explore new technology and to reinforce innovation as a strategic intent (Moultrie, Nilsson, Dissel, Haner, Janssen, & Van der Lugt, 2007). Yet prior research has addressed mainly physical design like open plan and office layout (Heiskanen and Heiskanen, 2011; Lewis and Moultrie, 2005; Oksanen and Stahle, 2013).

On the other hand, with the rise of Open Innovation (OI), firms recognize the importance of external sources and the need to manage internal and external flows of knowledge to foster internal innovation (Chesbrough, 2006). Firms implementing OI practices such as the search

for ideas in user communities (Von Hippel, 2005), open source development of new products (West and Gallagher, 2006b) and crowdsourcing (Afuah and Tucci, 2012) use Internet virtual platforms as instruments of collaboration. It seems that firms only use web platform for OI and physical spaces are restricted to internal innovation. Notwithstanding the collaboration of external actors with firms, research on physical spaces that support external collaboration has received little attention. Physical spaces should be one of the underlying decisions of OI implementation, a key piece in how firms maintain external relations, which adds to the understanding of the process of sourcing external knowledge (Dahlander and Gann, 2010).

Furthermore, the workplace is evolving and responding to social and technological change. Firms are creating spaces that fit their needs like Zappos, which adopted a new model that weave together public and private spaces, living and working, betting that this will make the firm in the long term more productive and innovative (Waber, Magnolfi, & Lindsay, 2012). Innovation is happening beyond firm's boundaries. Users innovate outside organizations, by their own, even when firms host them (Jeppesen and Frederiksen, 2006) and more people work in co-working and makerspaces. Such places are the meeting point for diverse groups and are becoming relevant for innovation and collaboration (Lindtner, 2014).

Many firms, e.g. BMW, Novozymes, Ford Motor, are jumping into this trend. Nevertheless, the decisions to support the creation of alternative spaces or collaborate with them to advance their 'innovation agenda' are based on instincts rather than evidence. Firms have difficulties to assess the degree to which R&D labs or innovation facilities help to achieve firm's innovation goals, in part because of the lack of clear objectives towards spaces (Moultrie et al., 2007). Assuming that firms' strategic intent "may be translated into specific innovation environments" (Moultrie et al. 2007, p.55), having clear objectives about spaces is key to understand the link of physical spaces with external collaboration for innovation.

I conduct an explorative study to better understand how firms' OI objectives drive the establishment of physical spaces. I draw upon attributes of liminality (Turner, 1967) that can characterize places and provoke feelings, induce action, and experimentation on people (Howard-Grenville, Golden-Biddle, Irwin, & Mao, 2011; Turner, 1987) to answer the following research questions: *How do firms establish physical spaces that facilitate the implementation of open innovation objectives?* H*ow do spaces contribute to experiences that affect innovation and collaboration?*

The settings are three spaces used by Open Source Hardware (OSHW) firms: a headquarters (HQ), a living lab and a sponsored makerspace. OSHW firms produce tangible products, which makes the physical space relevant to collaborative development efforts. Their collaborative arrangements are similar to user communities, who collaborate with firms in innovation activities (Lüthje, Herstatt, & von Hippel, 2005) rather than involving a group of actors working toward an integrated design (Raasch, Herstatt, & Balka, 2009a).

The contribution to the OI and innovation spaces literature is two-fold. First, to date the literature has a strong focus on the web platforms to enable OI practices and assumes the physical environment for internal innovation. My study attempts to challenge this view, I developed a conceptual model that links firms' OI objectives to the human experience of physical spaces through the combination of four liminal mechanisms (*allegiance, informality, diversity and temporality).* Second, the study drives attention to factors additional to and distinct from aesthetic arrangements (Heiskanen and Heiskanen, 2011; Lewis and Moultrie, 2005; Oksanen and Stahle, 2013) by identifying dimensions that characterize liminal and interstitial spaces as the mechanisms that facilitate the conditions for collaboration and creativity.

The study also adds to the stream of research that uses the liminality concept as a lens to explain organizational phenomena like strategy workshops (Johnson, Prashantham, Floyd, & Bourque, 2010) and organizational change (Howard-Grenville et al., 2011). It provides empirical evidence to support theoretical assumptions that specific types of spaces (liminal/interstitial) create favorable conditions for creativity. From a practitioner point of view, the model can be a guide for the creation of spaces with the appropriate set of liminal features so that the firm can achieve its innovation goals. It also outlines trade-offs derived from the use of liminal dimensions.

Next, I present a theoretical overview on spaces in organizations and how they can support to innovation and collaboration. An introduction to the liminality concept and its spatial dimensions ends the section. Following this, I describe the methodology and sample. Then I introduce the cases and compare the liminal dimensions of the three spaces and examine their variance in the Findings section. Drawing upon the findings I propose a conceptual model for crafting liminal spaces, with the implications for theory in the Discussion section and conclude with limitations and further research.

4.2. Theoretical Background

4.2.1. The impact of organizational spaces on organizations

The study of organizational working spaces has had an emphasis on the physical design and its impact on cost efficiency and effectiveness of organizations. It can be divided in three streams of research: a) Health, safety and comfort issues, b) A support for work processes, and c) Firm's internal and/or external expressions (cf. CABE, 2003). In the first stream of research, the concern is on the relationship between perceived comfort and self-reported productivity (Leaman and Bordass, 2004). One critic to this stream is that while the metrics and tools applied to individuals are important and useful, what makes the organization succeed is the collaboration of people, thus attention should also be paid to group interaction (Waber et al., 2012).

The second stream investigates how spaces support processes and help the organization in their ability to respond to changes in business and technology, to increase innovation rates and creativity, to create knowledge and to improve or develop skills of employees. The research interests have been in how the physical characteristics of spaces (e.g. open plan, office layout) impact organizational processes, communication (Allen, 1997), concentration (Banbury and Berry, 1998) and collaboration between individuals. Some studies highlight the importance of proximity in spaces and face-to-face interaction to enhance coordination (Allen, 1977). Research has shown that when people are situated in the same building, same floor and belonging to the same department, the propensity to form collaboration is higher (Kabo, Cotton-Nesslerf, Hwang, Levenstein, & Owen-Smith, 2014).

A third strand of literature on organizational spaces covers how spaces communicate the belief and values of the organization. Internally, spaces help to attract/retain employees (Myerson and Ross, 2003) and can be manipulated to make employees to identify with the organization while maintaining employees' self-fulfillment (Dale, 2005). Externally, buildings and offices send a message to external parties as they embrace both communication and branding, e.g. Apple, Amazon and Google are building or planning HQ that could win Architecture prizes (Rigby and Barr, 2013) signaling leadership and dominance. Thus, firms are using spaces to shape public perception and spell competitive advantage, attracting and retaining customers and shareholders (Bradley, 2002).

Facebook HQ illustrates how spaces serve to firms and how intentions are entangled. The famous architect Frank Gehry was hired to build "the largest open floor plan in world - a single

room that fits thousands of people… and it's easy for people to move around and collaborate with anyone here" (Zuckerberg, 2015). The CEO intentions for the space are first to be a support element for work processes, in specific he wants to foster collaboration among employees and second the expression element is present, by hiring a famous architect to build the HQ, the firm conveys a powerful image and attracts stakeholders.

4.2.2. Spaces supporting innovation and external collaboration

Looking deeper into spaces created specifically to support firms' innovation, previous research has shown that although the benefits of having an innovation lab seem to be contingent to specific applications and operating context (Lewis and Moultrie, 2005), according to Moultrie et al. (2007), innovation spaces support firms' goals in several ways: a) strategic, to support the firm's basis of competition, b) symbolic, to reinforce the firm's innovation strategy and corporate values, c) innovation efficiency (lower costs, productivity, improve speed) and d) effectiveness, to increase the quality and quantity of new ideas and improve the chances of new products succeeding, e) capabilities, to develop specific capabilities, f) teamwork, to encourage formal or informal interaction and communication and g) to enable customer input in the innovation process.

However, the idea of using spaces to support innovation has an over emphasis on addressing physical design, on how the characteristics of the spaces can support innovation within firm's boundaries (Heiskanen and Heiskanen, 2011; Lewis and Moultrie, 2005). And little attention has been given to how physical spaces support firm's goals related to external collaboration. New practices such as working from home or the use of co-working spaces are increasing and more entrepreneurs use public spaces, where people meet and interact. The conception of the workplace as "bounded and different from other spaces such as home and spaces for leisure" has changed (Dale and Burrell, 2008, p. 100).

Additionally, innovation is happening in spaces such as libraries and entrepreneurship centers. These alternative spaces to organizations' internal labs, where Internet connection or co-creation experiences are provided (Oksanen and Stahle, 2013) and public spaces such as coffee shops became the real innovation centers (Dillon, 2008). Furthermore, due to the high living cost conditions, owners of those spaces place several lines of business, e.g. gallery, co-working space, training facility and/or café, in the same site and end up being neither one thing nor the other. This ambiguity affects the experiences of the people using spaces and the innovation performance in positive and negative ways.

This just reveals that new needs and practices require alternative ways of organizing in alternative spaces (Dale and Burrell, 2008). Fab Labs, Hacker spaces and Tech shops are evolving in parallel to research labs and design studios and constitute a new trend to support creativity and entrepreneurial activity (Lindtner, 2014). Though empirical measurement for the effect of their spatial configuration on social interactions and economic outcomes remains obscure (Assenza, 2015).

4.2.3. Liminal and Interstitial dimensions in spaces

A way to explain what is happening with alternative spaces is to turn to the conceptualization of liminal and interstitial spaces, which suggests that the space' features have an effect on the behavior of organizational members and their relations with others. The attributes of liminality (Turner, 1967) can characterize places and provoke feelings, induce action, and experimentation on people (Howard-Grenville et al., 2011; Turner, 1987). A liminal space is "the boundary of two dominant spaces, which is not fully part of either" (Dale and Burrell, 2008, p. 238). In a liminal space, there are opportunities to meet people with a different culture. It is a place for ambiguity on *allegiance* and *identity*, i.e. people can owe allegiance to the worlds that meet in that place and to neither of them.

For instance, firms started to setup spaces that fit their needs, like Zappos, which adopted a new model that weave together public and private spaces, living and working, betting that this will make the firm in the long term more productive and innovative (Waber et al., 2012). And 'public-private liminal spaces' such a shopping malls in office buildings, invoke experiences in between 'work' and 'leisure' and become a feature of workplaces that foster consumerism (Dale and Burrell, 2008). Leisure also has the potential to release individual and communal creative power (Turner, 1977). Within the organization, liminality can be crafted in everyday experiences, the idea is to provide participants with the opportunity to experiment and the key resides in the "ability to invoke liminality as an insider" (Howard-Grenville et al., 2011, p. 537).

Similar to spatial liminality, interstitial spaces are small, in-between spaces, where diverse groups of individuals interact occasionally and informally around common activities (e.g. hobbyist clubs, workshops) rather than within an organization and where novelty arises from collective interactions. The dimensions that characterize the interactions in those places are *diversity*, *informality* and *temporality* (Furnari, 2014). Both spatial and interstitial liminality can facilitate behavior to get certain outcomes. For instance, the liminality lens has been used

to analyze strategy workshop-participants, who had a restricted access to a space, which is different from the office of their daily interactions. The emotional and cognitive commitment of participants lead to behavioral dynamic within that influenced the success or failure of the workshops (Johnson et al., 2010). For this study, the liminal spatial dimensions are the means for developing an explanation about spaces that foster innovative behavior.

4.3. Method

4.3.1. Research design and setting

To identify how firms create spaces to support firm's objectives related to open innovation, I followed an inductive approach with case studies (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). The case study method as Yin (1993, p. 59) states "investigates a contemporary phenomenon within its real-life context and addresses a situation in which the boundaries between phenomenon and context are not clearly evident". I also use a comparative analysis of the cases contrasting a HQ with other ways of organizing in alternative spaces. I do this with the analysis of texts (archival data) and the help of visual data (pictures) to examine liminal dimensions of the spaces and to a certain degree how people experience or use the space. Pictures are an aid to overcome the limitation of geographical distance to visualize the space without being present or intrusive, they document the space, the actors and their natural order (Bohnsack, 2008).

OSHW firms in the electronics sector are the setting for this study. The firms design and sell open source physical products such as microcontroller boards. According to Enkel, Gassmann, and Chesbrough (2009) firms in high-tech industries such as electronics and Information Technology (IT) integrate externals in a higher percentage (in almost 50% of R&D projects). Further, for OSHW firms 'openness' and 'sharing' are priorities, they produce physical goods "whose design anyone can study, modify, distribute, make or sell the hardware based on that design" (OSHWA, 2015). Besides to hold interactions with communities online and offline, the open source model helped firms to decrease the cost of the products using the work of OSS developers for the software, the support of users in forums and to make them accessible to groups beyond electronic engineers. In spite of firms' openness, their user communities have difficulties to share hardware components, so the work is conducted in small-scale collaborations (Mellis and Buechley, 2012).

4.3.2. Data collection

Prior studies have shown that the opportunities to collaborate are positively influenced by the firms' technical capital (Ahuja, 2000). Therefore, to find firms that engage in external collaboration, I gathered data from OSHW firms with an established reputation in the field and with evidence of external collaboration reported by the media. After making a list with all the spaces owned or sponsored by OSHW firms (around ten spaces with diverse uses), three cases were purposefully selected based on the theoretical concepts and liminal features. The characteristics of the three cases are presented in Table 4.7.1.

The data collected comes from the following three sources:

Archival data. Primary data comes from blogs and forums in companies' websites, members of the user community and articles in key industry publications such as Wired and Maker magazines available online and Factiva database. In all, around a hundred news articles were gathered about the cases. I also collected images and photographic material of the spaces from publicly accessible websites, including photos from Flickr and the author took photos of one of the spaces during a visit. Pictures can record personal insights of spatial and social relationships and even capture the cultural context (Knoblauch, Baer, Laurier, Petschke, & Schnettler, 2008). Since the cases are located in three different continents, with the collected pictures I could overcome the limitation imposed by geographical distance.

Semi-structured Interviews. I conducted four interviews with founders of the organizations, five interviews with diverse stakeholders, members of the community and one with a FabLab manager. The stakeholders do not necessarily visit the studied spaces but belong to the community or attend similar places. I conducted interviews by phone, Skype, email and face-to-face, which lasted between twenty minutes to one hour, and the majority was recorded with permission. The recordings were transcribed verbatim. The interviews with founders consisted in general questions about the company, OSHW challenges, their innovation process and how they interact with the community whereas community members were asked about motives and preferences attending events or belonging to groups to identify patterns.

Participant and non-participant observations. I participated in two workshops, attended two major conferences in the field: the 2014 OSHW summit and Maker Faire in Rome, Italy. In addition, I did short visits in 2015-2016 to four FabLabs located in Mexico, UK, Italy and Germany. I attended Arduino Day 2016, Torino (Italy) Maker Faire 2016, Mini Maker faires

in London, UK and I visited one of the cases located in Torino, which was hosting the Share festival. The observations were valuable to get insights about the people and the physical context. The participation in the conferences and workshops gave me first-hand view of the participants, startups and firms in the OSHW market and the creativity displayed in those scenes. A summary of data and sources is presented in Table 4.7.2.

4.3.3. Data analysis

In the first step of the analysis, I chose four OSHW organizations and made a list of the spaces they owned or sponsored. I eliminated one of them, which did not meet the requirement of using spaces, thus I examined the remained three firms, their spaces and intended purposes. I grouped firms' objectives into themes for all the spaces, to single out specific goals about open innovation. The objectives of collaboration, development of a community and the productivity goal are the main concerns that emerged from the list of spaces. Finally I selected three spaces based on their variance along the studied dimensions and potential theoretical impact to understand innovation spaces (Gerring, 2007). Two cases are exemplars of alternative spaces and a third case is a HQ. The cases and their purposes or objectives are presented in Table 4.7.3.

In order to develop the idea that certain spaces with a set of liminal dimensions lead to creativeness and innovative behavior, I followed a comparative approach with the three spaces. An alternative space is a space with diffuse identities or multiple functions (Dale and Burrell, 2008). The study is based on two assumptions, one is that firms' strategic intent towards external collaboration "may be translated into specific innovation environments" (Moultrie et al. 2007, p.55) and the second is that different sites have a variance in the following set of liminal dimensions: *allegiance, informality, diversity and temporality*.

Allegiance/identity means that the users of the space are allowed to have multiple, temporal or marginal identities (Dale and Burrell, 2008). *Informality* refers to occasional and informal interactions, the lack of frequency, structure, organization and formal obligations. *Temporality* denotes focused, physically and temporally bounded social interactions and *diversity* indicates whether people from different fields, e.g. profession, nationality, etc. use the space (Furnari, 2014). To assess the degree in each dimension I rated them using a scale with the values low, moderated and high. For instance for the temporality dimension, a high rate means a very short

duration of the interactions (e.g. some hours in a day), whereas a low rate is a daily interaction for a long period of time (e.g. 1 year) and a moderate rate is in between these two extremes, e.g. several weeks or months. Table 4.7.4 presents the comparison.

A second step was to review the information about the spaces to build a profile, about its visitors, open times, etc. I analyzed the pictures, which I interpreted according to the theoretical liminal features such as leisure elements, animals, etc. Pictures also document people visiting the spaces, information about the gender, age, what they are doing and corporality and facial expressions. Thus, I could form an idea of the demographics by observing pictures and validating interpretations against text information found in other sources like news or firm's websites (Bohnsack, 2008). Similarly, objects in the photos representing the theoretical elements of spatial liminality can be complemented with insights from other sources, e.g. the implementation of rules to handle informal work situations (dog policy) and profession or background of visitors. The comparison of the liminal dimensions was important to derive the propositions in the discussion section.

Finally, I codified the experience and feelings found in the spaces. I constructed a comparative table with representative quotes from press articles together with information in the firms' website and public forums. The quotes reflect people's perceptions about the use of the space and/or interaction in the three spaces. In this way I got the local knowledge of the people visiting, experiencing the place and "an intimate understanding of what is generally true in the locally obvious" (Casey, 1996, p. 45). During the coding process, I compared the data codes across the sources (semi-structured interviews and field notes) to identify inconsistencies and to strengthen internal validity.

4.4. Findings

4.4.1. The cases and the collaboration goal

The three spaces were set with explicit objectives or purposes expressed by the firms' owners or sponsors of the spaces. SparkFun had in mind operational needs and a good work environment for the construction of its HQ. In contrast, two firms Arduino and Seeed Studio set up dedicated spaces with the intention of building and collaborating with local communities. The two alternative spaces are Arduino-Casa Jasmina, a living lab, and Chaihuo, a sponsored makerspace funded by Seeed Studio. The objectives for the HQ differ from the ones in alternative spaces. The HQ has a long-term purpose while the goals for the alternative spaces

originated from personal initiatives of CEOs. In all the cases, there is an implicit objective, to support growth. The three cases with context details are presented next.

SparkFun HQ

SparkFun HQ is located in Colorado, USA. It has had three different locations within the city. The current building hosts an open space office with warehouse and other operational areas. The founder was involved in all the aspects of building the HQ during 2013-2014, with the main goal to support business holding administrative and production activities and at the same time build a social environment that motivates employees and boosts productivity.

> *In designing the new building, we worked closely with the architects to create a space that will* ***be utilitarian for SparkFun's business-y needs, but also foster community and interaction between SparkFun employees*** *with things like a larger exercise space (with a climbing wall!), a single break room (instead of the multiple separate ones we have now) and an open design between departments. (SparkFun founder and CEO)*

SparkFun HQ has an unconventional and an informal work environment with many relaxing rules such as casual dressing codes, dogs, beer consumption and perks like a climbing wall and use of skateboards in the office. There is *diversity* in terms of personalities and interests. However, the firm's employees have limited contact with outsiders within the building. The development of a relationship with the community is mainly through the firm's website, blog and forum.

The staff interacts with the public in occasional events and/or temporal programs. The temporal arrangements bring serendipitous encounters, for example the hacker-in-residence program, running from 2013 to 2015. In that program, individuals or small teams external to the organization explore ideas and build small projects with SparkFun. The firm hosted participants for a period of time (in average two weeks) in its facilities, during which the visitors met employees, who could advise and contribute in the projects. The participants with various backgrounds and from different firms, institutions and geographical regions had the possibility to use materials provided by SparkFun, exchanged experiences and share the results usually in a blog. Some of the projects can be commercialized (e.g. SparkFun CryptoShield). The firm reaches a broader audience through training, workshops and competition events that bring the general public for a day to SparkFun facilities such as an autonomous vehicle competition. The

acceptance of such event has prompted the firm to charge a fee just to assist to the annual competition, even if one does not compete.

Casa Jasmina (CJ)

Arduino established CJ in 2014 as a living lab and a temporal program for two years, with the specific objective to foster open source and develop technology and design innovations on the Internet of Things (IoT). IoT is about connecting devices over the Internet, communicating with applications, each other and humans. One can say that the intention is to develop a capability. The space is situated in a renovated Fiat factory building shared with Officine Arduino, FabLab Torino and co-working spaces in Turin, Italy. Arduino intentions are to incorporate the local community and industry players in the project, to attract audiences and boost the industry in the region.

> *'Casa Jasmina' is a two-year pilot project in the business space of domestic electronic networking, or, 'the Internet of Things in the Home.' We are building Casa Jasmina in order to encourage industries that will create tomorrow's living spaces.*
>
> ***Casa Jasmina is an incubator**, and **its purpose is industry-boosting** in the Torino and Piemonte IoT space. 'The apartment will serve as **test bed for the latest development from the open source community.** (Arduino website)*

CJ was conceived with three functionalities in mind: lab, gallery and temporal apartment. The firm calls for participants (usually inventors and designers) to contribute with hacks, prototypes and original tinkering in exchange for brief 'residencies' in the apartment. The multiple logics: home, business and public spaces provoke ambiguity in the usability of the space. The space is not always occupied as a house, for periods of times CJ exhibits the work of collaborators. The holding of events by the other co-residents influences the fluctuation of people visiting the place. For instance, during the annual Mini-maker Faire the visit of 'makers' with their families increases, with people visiting all the building.

When it functions as a gallery, both individuals and firms can participate in an exhibition after a selection process. Firms contribute with products and equipment. The firm clearly states who owns the Intellectual Property (IP) rights to any material created in the space or for exhibition in space.

Chaihuo Makerspace

Funded by Seeed Studio in 2011, Chaihuo is located in Shenzen, China. Seeed's founder noted how important physical spaces are for customers, while imparting a workshop in a hacker space and in connection with a group of makers called SZDIY, a community in need of a space, he offered them one and created Chaihuo. Now it is a non-profit space sustained by memberships. The makerspace operates through regular, VIP and resident memberships, i.e. people pay membership fees to use the space. Though SeeedStudio sponsors and the CEO of SeeedStudio is Chaihuo's general manager. A sponsored makerspace is different from a corporate makerspace, where only employees of the firm can go there to tinker, e.g. Microsoft Garage. In Chaihuo any person from the public can visit the place, subject to acquiring a membership.

Seeed Studio has the goal to build a community of makers and to use the space to promote a culture where making can be fun, but the Chinese attitude to experimentation is different, the fear to fail and lose face is much more serious than in western countries. As one of the earliest makerspace initiatives in China, Chaihuo is embedded in the Chinese supply chain ecosystem, at the heart of manufacturing networks, in a cluster of electronic suppliers. Therefore, objectives towards the space are influenced by local needs; the incentives to visit the place are less based on the use of tools than on the collaboration among members with the aim to develop a commercial product.

The makerspace not only fosters the entrepreneurial spirit but also helps the firm to get customers. The members of Chaihuo see the firm as the first option to go for manufacturing. Initially the makerspace had difficulties to gain traction, thus it was moved to a neighborhood more appealing to visitors, near shops and cafes, where designers and tourists gather. Chaihuo has evolved since its inception to a combination of makerspace and incubator, where companies use a VIP space in a different part of the building for free in return for a cut of the business.

The space has areas with different functions: infrastructure area, sharing area, VIP office and makers' products store, equipped with basic making tools, such as 3D printer, laser cutting machine, electronic equipment, etc. People work in their projects, ask for help to other people working on the site and engage in a creative process, some of them are transferred in a mature state to an accelerator space leading to a commercial innovation.

> *I see Chaihuo as so different from any other hacker space because it's in Shenzhen and the people here are more* ***focused on not only making some fun projects but also in***

***turning them into real products**, to commercialize as a startup. (SeeedStudio CEO & Founder).*

Among the members are DIY enthusiasts and entrepreneurs, who form groups of diverse interest or expertise including SZDIY, the Android-loving group, iOS Party, Microsoft Club, SZHAM and Amateur Radio Group. Recently Chaihuo has established contracts with schools, which brings younger generations to learn and experiment with tools and create artifacts and the general public can do a free visit twice in a week, during the open days. The collaborators of Chaihuo include several designers and organizations such as Google, Microsoft, MIT, NASA and MAKEZIN.

In sum, the three firms set collaboration objectives for the spaces, but in SparkFun HQ the interest centers on employees whereas in the other two spaces the focus is on external actors and local communities.

4.4.2. Liminal dimensions comparison

The findings suggest important differences between the HQ and alternative spaces for each of the four liminal dimensions that affect the conditions created for collaboration. The data show that the degree of *informality* and *allegiance* is higher in alternative spaces than in HQ spaces. In CJ, there are not specific rules except for a request of a contribution. Visitors follow social norms and questions and behavior are made without being too intrusive. In the makerspace, it is up to the individuals or teams and their personal incentives to have a progress in their projects or learning. There is not fixed scheduled time or dress code, which allows the visitors to feel a higher degree of autonomy. In both cases the visitors can be and do whatever they want, with no formal evaluation but to share the project and their experience.

Compared to the two alternative spaces, SparkFun HQ has a moderate degree of *informality*. Despite the office space offers islands of informality and relaxing rules such as drinking beer or a wall doing rock for climbing, there is a pressure for productivity and to align with the goals of the firm. Temporal visitors are subject to less control, but still have the pressure to present their projects at the end of the visiting period. *Informality* contemplates the lack of frequency of the interactions, which complements the temporality of the interactions.

In relation to *temporality*, all the spaces, HQ and alternative spaces organize events with a short duration that can happen in a periodic basis. In SparkFun HQ the duration of a contest could last a day but with an annual recurrence. In the same way, the social interactions between members in the makerspace are short-term and can be recurrent, apart from sharing working

place and tools there are periodic meetings to showcase projects. Whether the same people participate is another issue, unlike the previous examples CJ has a high rate in the temporality dimension with interactions with no recurrence, e.g. one-time guests or participants, who are not personally present in exhibitions.

Regarding *allegiance* or *identity* assumed in the space, like in any firm, in SparkFun HQ, work identity dominates other social identities, though temporal visitors keep their own identity. While in alternative spaces, the *identity* is ambiguous and can be determined by the context and the individual. Visitors of the makerspace can use the space to work in projects with a personal interest as a hobby or with an entrepreneurial orientation, but there is not any demand from the owners of the space. The purposes for the space have implications for the *diversity* dimension, in terms of target groups visiting spaces, e.g. designers, makers, or the public. Depending on its function, CJ has visitors with specific skills (e.g. IoT, open source) when functions as an apartment or the public when functions as a gallery and there is general interest exhibition (e.g. slow food events). Yet CJ attracts alike type of visitors. Similarly, Chaihuo makerspace allows both specific and public visitors. The interactions in SparkFun HQ are mainly within the organization, thus I rated its diversity as low. In contrast, the makerspace accepts people from different fields as long as a membership is paid. A summary of the comparison of liminal dimensions among the three cases is presented in Table 4.7.4.

4.4.3. Experiences and feelings about spaces

This section shows the outcomes based on experiences or feelings of participants. Visitors expressed experiences, feelings and practices developed about and within the spaces, which are presented in Table 4.7.5. These three elements constitute the evidence of how the space influences and shapes interactions. First to mention are two feelings: Flexibility and having fun. The data show that visitors and users of the three places perceived an environment with flexibility, where there are relaxed rules and even CJ has not clear defined rules yet. SparkFun HQ blends office and leisure features and employees establish rules collectively like a dog policy. Meanwhile for external visitors, annual competitions provide fun and the opportunity to use the facilities and available equipment for presentations and discussions with the external participants. In general, a relaxed environment is more evident in alternative spaces because they have less structure and accept informal behavior. The managers of CJ only request to leave a contribution and to share the results generated during the visit. There is a sense of

permissiveness and autonomy, visitors have opportunities to define the space, the social relationships and rules as a visitor explains:

> *The rules as a guest—and as a host—have not been written yet. The relationship is being negotiated, as is the space itself. Norms get to be re-imagined and invented. (Visitor Casa Jasmina, 2014)*

Likewise Chaihuo makerspace has a focus on social stimulation, since the region has affordable services available. Contrary to other makerspaces in western countries, it does not have a lot of equipment but provides an environment where its members can develop their ideas. Participants start working in projects as a hobby until they spot a commercial opportunity and get the financial support to develop it. On the whole, the feelings and experiences such as having fun and flexibility are accentuated in alternative spaces, in which people find a supportive and flexible environment. The visitors associate these feelings to the creation of ideas and new norms. In a HQ, these features made a good environment but the too much permissiveness can lead to people not doing their jobs and take advantage of it.

Another point is that some visitors' experiences depend very much on the *diversity* perceived. Despite the claims of SparkFun CEO about being a firm with a diverse workforce, the findings suggest that cross-field interaction is limited. In its new product development process inputs from customers comes through the web site forum or in events but there is only one employee dedicated to fuel the new product pipeline. Furthermore, the selection of ideas to be produced is made by a group of engineers. However, external collaboration happens in the form of temporal program or events such as 'Hacker in residence', when non-employees collaborators worked in projects sometimes. The staff expressed positive feelings:

> *I think* ***diversity is one of the most important features of the open source movement,*** *and creating spaces like the Hacker-in-Residence program is vital.* ***You never know which new ideas can be sparked from such an awesome environment****. (SparkFun employee)*

On the other hand, there is also a sense of identification; the visitors can be part of specific groups such as interaction designers and geeks, 'makers', entrepreneurs and students. The other side of the coin is that this might result in engagement barriers, the general public might feel intimidated to visit the place due to perception that technical skills are compulsory to be part of those groups. There were attempts to address this issue, for example CJ functions as a gallery and with this objective for the space the management did attempt to change the perception of

private boundaries of the space to a public place. And Chaihuo, which visitors are mostly designers, engineers, recently opened the doors to a wider audience, children from six years old to adult students. More over, Chaihuo calls for a period of residency target western visitors in exchange of creating projects, giving workshops and meetups to members and the community around it.

Finally, the visitors mention collaboration, learning and sharing practices. Those practices can be recognized as values of the open source philosophy and part of the firms. However, the firms craft experiential scenarios to encourage leaving a contribution in exchange of visiting the place or as part of the attitudes expected in the place. There is visible action, in SparkFun HQ with its temporal hackers, who build projects with the help of internal employees and in alternative spaces, 'sharing' is an integral part of the creation of the space. And Chaihuo organizes sessions to showcase projects.

4.5. Discussion

As physical spaces are means that can both constrain and enable action (Senoo, Magnier-Watanabe, & Salmador, 2007; Nonaka and Takeuchi, 1995), this exploratory study aims to understand how firms establish physical spaces to enable firms' strategic intention towards openness in terms of collaborating with local communities. Building upon the idea that firms' strategic intent "may be translated into specific innovation environments" (Moultrie et al. 2007, p.55), I propose a conceptual model that outlines how firms create innovation environments but rather than linking the firms' strategic intent directly to the physical characteristics of the innovation environments, the model considers the innovation goals as inputs that guide the tuning of a set of spatial-liminal dimensions. The consideration of liminal dimensions in the model is a new perspective of how to influence innovative behavior within spatial environments.

4.5.1. A model for crafting liminal spaces

The model, presented in Figure 4.7.1, connects three components: a) firms' innovation objectives, b) the features of liminal spaces, i.e. a set of four liminal dimensions and c) the outcomes generated by the combination of different levels of the liminal dimensions. The first component basically refers to the articulation of the firm' goals. A strategy of innovation requires the understanding and articulation of the what, when and why of innovation activities, how those activities can create value or are aligned to a business intent, i.e. achieve a product

or service performing better, faster or easier, whether the product is more convenient to use, more reliable, cheaper, etc. (Tidd and Bessant, 2013). An innovation strategy is important because it helps firms to understand which innovation practices fit the organization, testing them against the market, technologies regulations and competitors and gives clear directions on how to allocate resources (Pisano, 2015) leading the firm to higher competitiveness.

Firms with an OI strategy incorporate external sources of knowledge (Chesbrough, 2006) and have to define whom to partner with, the duration (long vs. short term), the scope (internal vs. external) to guide their decisions. SeeedStudio and Arduino defined their OI objectives in terms of collaboration with local communities and established two different alternative spaces, in addition to their HQ. In contrast, SparkFun built its HQ with a more operational goal and business purpose plus a good environment for employees. In the model all these objectives are represented as the inputs that inform the definition of the liminal dimensions.

The second component of the model refers to which degree the spatial dimensions vary in the different type of spaces. And the third component derives from the relationship between the variance of the liminal dimensions and the feelings and experiences of visitors. The perception of people is very central to the concept of place (Casey, 1996). And this is manifested in previous research with primarily focus on the physical characteristics (functional and aesthetic) of organizational spaces, for instance, there is a relationship between the 'perceived' comfort and self-reported productivity (Leaman and Bordass, 2004) and also firms use spaces to shape public 'perception' (Bradley, 2002). However, there are other nuance conditions that convey and inform the generation of experiences, which can be created by crafting the liminal dimensions.

To begin with the discussion of how the relationship of the variance of the liminal dimensions affects the perception of people, I start with alternative spaces and the *allegiance/identity* dimension. Both Chaihuo and CJ allow people to assume multiple identities, i.e. people are free to be and do whatever they want, which generate an atmosphere where people feel excited about what they do and a sense of play and fun, which can stimulate creativity (Amabile, 1998) and collaboration. In contrast, in SparkFun HQ the workspace and recreational features that situate people in between work and leisure, created a relaxed environment but the work *identity* dominates other social identities of employees. This situation is beneficial for the firm since

during stages of heavy growth, spaces facilitate reasonable employees' autonomy and group identity (Heiskanen and Heiskanen, 2011).

Chan and Husted (2010) have shown that dual or multiple *allegiance* in the context of open source, i.e. the type of *allegiance* that individuals pledge to a firm and/or to the open source community, influences knowledge sharing behavior. The alignment of firms to the open source ideology influences how employees of OSS firms share knowledge with other community members and even on the time and effort employed in their work versus the community. Therefore *allegiance* is relevant to collaboration because both employees and participants external to the firm feel free to act and share.

In that sense, in alternative spaces people behave differently than in an office because they have personal agency regarding their behavior, not limited by pre-existing norms or any formal authority. There is flexibility, with no pressures about performance (Assenza, 2015). Therefore alternative spaces would generate better experiences than HQ that induce innovative and collaborative behavior. The corresponding proposition as follows:

> *Proposition 1. Alternative spaces are more likely to allow higher degrees of flexibility in membership (allegiance) than a HQ, which provoke feelings of flexibility and having fun as well as encourage learning and sharing practices.*

Another liminal dimension that impacts collaboration is *diversity* in both positive and negative ways. I adopt a wider definition of diversity that encompasses demographic variables (ethnicity, gender, age) and it is often mixed with *diversity* as variety in functional background and levels of skills. The data show that the use of firm's products in members' projects, the provision of services for members, ideas for firm current or future products and identification of people with skills to hired or collaborate are among the benefits that firms can get by having an heterogeneous group of people as visitors. Nevertheless, *diversity* may also inhibit collaborative behaviors. Previous studies have found that greater variety of background and experience affects the willingness to share knowledge (Gratton and Erickson, 2007).

In addition, firms might face difficulties in maintain many relations and would experience some inertia with consistent patterns of collaboration over time due to socialization (Dahlander and Gann, 2010). To have *diversity* and break the routine, firms established temporal programs, like CJ and Chaihuo calls for residencies and SparkFun's 'hacker in residence', which hosted individuals or a small group of people from different firms or institutions for a short period of

time. Thus, an interesting project, skills and backgrounds made possible collaboration with external actors.

On the other hand, the limitations of contemporary life regarding real state rents make public spaces (either free or paid for visitors) increasingly popular. Firms are increasingly creating private-public spaces to ensure not only *diversity* of visitors but also some levels of control; alternative spaces are exemplars of such approach. In comparison to HQ, alternative spaces allow higher levels of *diversity* because regardless of memberships and other selection mechanisms, they are more exposed to the public. In addition, the support of learning and sharing practices of high value for the community.

Yet there is no guarantee to achieve high levels of *diversity*, there is a risk that such specialized spaces scare normal people and only attract homogeneous groups. For example, CJ was perceived as a living lab for certain type of visitors and it had to change its image to function as a gallery/museum open to the public. Another way to enhance *diversity* observed in Chaihuo case is the free entrance once a week to any person who wants to make use of the space. In addition, a service approach might help to minimize the challenges of high *diversity*. Services such as the provision of Internet connection or co-creation experiences would help to build relationships (Oksanen and Stahle, 2013).

Thus, it is advised to balance *diversity* by managing the space image and mechanisms for admission and use. The idea is that communication among members is possible and not broken by differences. The corresponding proposition as follows:

> *Proposition 2. The higher the levels of diversity in spaces the greater the chances of creative output and the weaker the sense of group identification, which affect the willingness to share and the perception of the space.*

Regarding the *informality* dimension, there are two components, one refers to informal or relaxed rules in interactions that give people a sense of freedom to do or work in projects they are really interested in, whenever they want, with not fixed schedule or dress codes. The perception of freedom makes room for individuals to be creative, to create and experiment in self-organizing manner and informal environments (Augsdorfer, 2008) and even enables new forms of relating (Howard-Grenville et al., 2011). Especially the freedom of expression and the freedom to experiment give a sense of control over one's work, which are fundamental to creativity (Amabile, 1997, 1998; Andriopoulos, 2001). On the contrary, high levels of control affect negatively the motivations of participants as happen in OSS communities (Shah, 2006).

Despite informal dress codes and leisure elements that employees experience, SparkFun HQ has a hierarchical structure that dictates the goals to follow and there is limited interaction with external actors. Whereas alternative spaces are environments in which participants experience high degrees of *informality* and where failure is accepted. The policies are a mix of social norms, codes of conduct (cleanliness, smoking, etc.) and safety rules for the use of equipment. Additionally, location and culture also have an influence the levels of *informality*, e.g. while in CJ there is not a formal evaluation, visitors only present the result of their work, in Chaihuo participants are more entrepreneurial oriented and driven by the commercial success of their inventions.

The second component of the *informality* dimension to examine closely is the lack of frequency in social interactions. It may have a close association to the *temporality* dimension, which indicates interactions happening in a relative short period of time, transitory interactions that eventually breakup over time (Furnari, 2014). 'Hacker in residence' from SparkFunHQ, Chaihuo and CJ temporary hosting for weekends or the whole summer illustrate the frequency aspect of the *informality* dimension.

However, in order to provide opportunities for meaningful interactions, the frequency and the temporal duration of the interactions should not be extreme that jeopardize the possibility of collaboration. The interactions are transitory by definition; still the experiences lived together by a group of people within the spaces set the basis to form a community even after leaving the place (Johnson et al., 2010). The data show that participants in alternative spaces incur in periodic practices, e.g. attend periodically the place, projects showcase every month, which help to develop a community in the long term. In sum, firms should moderate the features of temporality and informality in interactions that allow the creation of ideas with activities that enable the building of relationships, e.g. periodic competitions and showcase sessions.

> *Proposition 3. Having moderate levels of informality and periodic interactions to share activities among visitors, e.g. showcase of projects, increases the likelihood of building relationships and collaboration within a community.*

4.5.2. Implication for theory

The contribution to the OI literature is two folds. First, I extend existing research regarding the implementation of OI practices by firms. Apart from firms selectively revealing information (Henkel, 2006) through web platforms and involving more extensively external sources in the

innovation process (Laursen and Salter, 2006), little consideration has been given to contextual variables such as physical innovation spaces. The research of innovation spaces brings more understanding on underlying decisions in the study of sourcing external knowledge, specifically in the maintenance of external relations (Dahlander and Gann, 2010).

Second, the study contributes to previous research on innovation spaces that links spaces to the firms' innovation strategy (Moultrie et al., 2007) and drive attention to issues that complement the characteristics of spaces to support innovation (Heiskanen and Heiskanen, 2011; Lewis and Moultrie, 2005; Oksanen and Stahle, 2013). Organizational spaces are a medium for the fabrication of a social environment and organizational culture, capturing hearts and minds of employees (Dale and Burrell, 2008) and a driver of behavior towards innovation. The model explains the logic behind private-public workspaces to improve people interactions and firm's innovation such as Zappos (Waber et al., 2012) and firms sponsoring or partnering with public spaces, e.g. Novozymes- BiologiGaragen/Labitat, BMW Group-Guggenheim Lab, Ford Motor-Techshop Detroit.

Additionally, the study joins to the stream of research that looks at liminality as a lens to explain organizational phenomena like strategy workshops (Johnson et al., 2010) and organizational change (Howard-Grenville et al., 2011). This study presents liminal dimensions as mechanisms that firms can pursuit in physical spaces to implement OI objectives and provides evidence to support the theoretical assumptions that specific types of spaces (liminal/interstitial) can provoke feelings or experiences that induce behavior such as creativity and experimentation.

4.6 Conclusion

This study shows the link between physical spaces and the implementation of firms' goals that involve external collaboration with local communities. To achieve their OI objectives, firms can regulate the degrees of liminal dimensions in their organizational spaces and get benefits with the establishment of alternative spaces, which complement the use of HQ (offices and internal R&D labs). The study substantiates that the physical space can be an instrument for firms to engage in external collaboration, a factor for knowledge creation, learning and creativity. Although the focus of the study was not on the physical characteristics of the space per se, it might inform other disciplines such design and architecture for the development of liminal functional spaces.

The study also points out challenges that should be addressed by the management: the trade-offs of the spatial dimensions. For example, having high *diversity* might bring new ideas and

approaches to product solving problems and new product development; at the same time too much differences among participants might make people reluctant to share knowledge. On the other hand, having homogeneity might facilitate communication and identification among members but harm the richness of ideas.

Finally, the model can serve as guidance for managers and for policy makers to create spaces with the set of liminal features appropriate for the firm's innovation goals and context. Beyond the physical characteristics of a space, managers can drive the composition of people, who use the space and influence the social environment in which they interact to foster innovation and creativity.

Limitations and future directions

There are several limitations to this study. Generalizability is among them, the results do not reflect the situation of innovation spaces for industries with tight IP and sharing information with outsiders is banned. However, the appearance of hacker spaces for biotech such as Biocurious in Silicon Valley (Biocurious, 2016), Genspace in New York City (Genspace, 2016) and hacker spaces for musicians are indications that other industries have started to discover the benefits of alternative spaces. Regarding the analysis of the data, another issue is that only the author did the coding and rating of the liminal dimensions, it would be useful that an expert could validate the findings and enhance external validity.

A second limitation is that the outcomes have only an indirect link to innovation performance. There is information about the projects or prototypes that collaborators developed within the space but no indication of the direct impact on the firms' product development. It would necessary to further explore alternative measurements to determine in what ways (quantitative or qualitative) the innovation spaces contribute to firm's innovation effectiveness and efficiency. Though there are contexts considerations, in general the model with the set of liminal dimensions can be applied to other industries that embrace more openness.

An additional avenue of research is modularity, task decomposition and knowledge distribution matter when taking the decision to open boundaries (Lakhani, Lifshitz-Assaf, & Tushman, 2012). Companies can selectively reveal the information by modularizing it and strategically choose which one will be available to the public (Henkel, 2006). Yet for tangible objects it will be a challenge to determine how the design files should be fragmented and be available to

external collaborators. Thus it would be important to know how design modularity could be carried out in physical spaces for external collaboration in firm's innovation.

4.7 Tables & Figures

Table 4.7. 1 Case studies' characteristics

	SparkFun HQ	Casa Jasmina	Chaihuo Makerspace
Location	Colorado, USA	Torino, Italy	Shenzhen, China
Function	Office	Living lab/ Incubator for IoT/gallery	Makerspace
Owner	SparkFun Electronics	Arduino LLC	Seeed Technologies Inc. (SeeedStudio)
Facilities	Office building with warehouse and production areas See Appendix A- Figure A.2 for visual material	Two bedroom-apartment, kitchen, living room/dining room, small roof garden, basic bathroom See Appendix A- Figure A.2 for visual material	Space in two separated buildings one for public access for makers and the other for entrepreneurs See Appendix A- Figure A.2 for visual material
Accessibility	Employees, but public can go in visit tours or occasional events	- By invitation or candidates can apply for a short period visit, submit work through public calls -The general public can attend exhibitions	Anyone that want to pay for a membership, open to the public in tours and show-projects sessions

Table 4.7. 2 Data sources

Data Source	Quantity	Type of Data
Archival Data	100	News, release reports from media
	80	Casa Jasmina pictures
	40	Chaihuo pictures
	50	SparkFunHQ pictures
Semi-structured Interviews	9 (70 double space pages)	4 founders and 5 stakeholders such as members of the maker community and OSHWA, including 1 Fab lab manager, 1 Casa Jasmina stakeholder
Websites	3	Firm websites from cases
Blogs & Forums	5	Firms & founders
Conferences presentations & workshops	24 presentations & 2 workshops	OSH summit Rome 2014
	30 presentations & 1 workshop	Maker Faire Rome 2014
	Induction	FabLab London 2015
	Course	FabLab Puebla 2015
	Observations	Minimaker Faires 2016 (London, Turin)

Table 4.7. 3 Objectives for the spaces

Objectives	SparkFun HQ	Casa Jasmina	Chaihuo Makerspace
Business orientation	to create a space that will be utilitarian for SparkFun's business-y needs, but also foster community and interaction between SparkFun employees with things like a larger exercise space (with a climbing wall!), a single break room (instead of the multiple separate ones we have now) and an open design between departments.	"Casa Jasmina" is a two-year pilot project in the business space of domestic electronic networking, or, "the Internet of Things in the Home", - its purpose is Industry-boosting in the Torino and Piemonte IoT space.	- …We will also set a booth in this space so people can easily buy stuff here and start playing with them immediately - Chaihuo has become the de facto incubator for Seeed Studio. When makers from Chaihuo come up with exciting new ideas, Seeed Studio usually becomes their natural choice to manufacture a small quantity for sales
Support growth	Besides adding office and warehouse space, the new headquarters building will include a video room and classroom, allowing SparkFun to expand its electronics education programming.	Our goal is to integrate traditional Italian skills in furniture and interior design with emergent skills in Italian open-source electronics. The project is a showplace inside the large industrial building with three main functions: A real-world testbed for hacks, experiments and innovative IoT and digital fabrication projects. A curated space for public exposure of excellent artifacts and best practices. A guest-house for occasional visitors to Toolbox, Officine Arduino and Fablab Torino.	Those young people really love these gadgets. Its' good to see people attracted but it's not good enough. We need to built[d] a space to let them play with electronics. So our next plan is move our office to a much bigger space, (1250 square meters) and the old office will open for all electronic hobbyist as a Hacker Space. (SeeedStudio website).

Table 4.7.3 (continued)

Testing new ideas and building a community	Let's build a set, build some projects and just keep adding to it. Eventually it will turn into the home of the future. Along the way, we'll talk about the build process and open-source all of our work so it can be replicated. The projects don't have to be too serious, but they should focus on concepts that are applicable in real life...Our first instinct was to use the un-leased, unused space in a corner of the building but after talking it over with Ops we decided it was no good. If the space got leased out, we'd have to move the set. However, that conversation led to our Director of Operations offering up some space near his office so we measured it out and decided it was exactly what we were looking for.	-The apartment will serve as test bed for the latest development from the open source community. - It's time to live the life. Just go ahead and build the products and see if you can survive being in a room with them. Casa Jasmina is our test bed. —*Bruce Sterling at ThingsCon*	- Chaihuo is dedicated in spreading maker culture and building maker community in China, as well as providing a platform for foreign makers to learn about China ecosystem. -To provide a platform that enables designers, DIY enthusiasts, inventors and makers to develop their ideas in a supportive environment, attend workshops and share their experiences, while occasional visitors can have a go in using controllers and circuits to make all sorts of things.

Table 4.7. 4 Cross comparison spaces' liminal dimensions

Space	Dimensions			
	Temporality	**Informality**	**Allegiance/identity**	**Diversity**
Casa Jasmina	**High** (temporary housing, guests of the house *stay for a limited period*) '*After spending two days there*, I came away with plenty of thoughts of the role of technology in our present and future homes'	**High** (Informal rules & no frequency in terms of different visitors each time) In 'a hotel room the assumption is that it undergoes a "factory reset" when the guest leaves: It's put back to its original state as much as possible. In an Airbnb situation, the guests can alter and adapt the space temporarily, but would take great care to ensure they can put everything back the way it was before. (The effect is similar to that of the hotel room, only the responsibilities are distributed differently.) *In a space like Casa Jasmina, of course, more permanent changes are not just endured but encouraged – it's a place to be hacked*.'	**Low** (As a living lab the social identities didn't change that much but people might be confused when the space is presented as a public space. 'we imagined three functions for the space. It would *be a laboratory, where we experimented with Maker Culture for housing*. Also, it would be a guest house, where our visitors could eat and sleep. The third aspect would be Casa Jasmina as *a showplace for the public*. In May 2016 we managed to transform the space from a "house" to a "museum." …Even if the Internet's windows seem to yawn wide open to every spy and ad-man alive, the conceptual walls between public and private are still tall, strong and stout. The public will never walk inside a private home without compelling reasons.) 'It isn't a home where people live full time as it is an open source design residency program. The only real private spaces are the bedrooms as the living room is more of a meeting room, the tv gets used for presentations and the kitchen is used to organise events on the nearby roof terrace. Does that make it a home or a lab or even a commune? …there's something public about the space right now, even without cameras'	**Moderate/High** -'*the public of Turin just doesn't much mingle with Toolbox, Arduino Office, Fab Lab or Print Club. These four groups inside Via Egeo rarely visit each other, even, except for seminars, training lectures, show-and-tell meet-ups, and the occasional nice barbecue up on the roof*... As an experiment, *it mostly interests certain groups of specialists in interaction design, electronics, and Maker culture*. - Via Egeo is also the headquarters of the Torino Mini Maker Faire. *On the last day of our event a huge swarm of Makers showed up, fabbers, Turinese steampunks, coders, students, kids, grannies, whomever*. Our attendance skyrocketed.

Table 4.7.4 (continued)

SparkFun HQ	**Low** (Permanent employees, visitors during events such as annual competition and Hacker in residence program with a duration of 1 day and few weeks respectively). 'We chatted with them about their plans and interests yesterday when they arrived at SparkFun from Los Angeles for their two-week adventure!' June 2013	**Moderate** (relaxing rules about dress code, beer drinking and pets at the office but hierarchy in place, frequency same employees, different visitors in temporal programs) The work culture here is pretty laid back; there's certainly no dress code. Also, over time people started asking if they could bring their dogs into work. My response was, "Well I'm not really a dog person, but if it would make you happier and you can take care of your dogs, go ahead and bring them in." Then the skateboards showed up, then the loud music. So now we have this wonderful culture of controlled chaos.	**Low** (the employee identity still dominate the personal ones) 'You can be treated like unskilled labor. the work of SparkFun and SparkFuns goals outweigh you always.' (Anonymous employee in Glassdoor website)	**Moderate** (The firms claims diversity in their employees, but there are just occasional external visitors during the year that engage with them)
Chaihuo makerspace	**Moderate** (24hr. membership with Office space and nights and weekend membership, regular meet ups, workshops and 3-4 makers or startups working)	**High** (Codes of conduct and social norms, members can change but have periodic practices) With around 1000 members (2015) 'it's about the people — [having] a place to share, a place to talk'	**High** Personal identities of visitors are not attached to any formal position or profession. SeeedStudio's employees compose the management of the makerspace.	**Moderate** (Visitors are engineers, hackers, entrepreneurs and students from primary and secondary schools) 'Chaihuo Makerspace, has signed contracts with 42 local primary and secondary schools to promote innovation education among students.' SeeedStudio website

Table 4.7. 5 Cross comparison experiences

Experiences	Arduino (Casa Jasmina)	SparkFun (HQ)	Seeed Studio (Chaihuo makerspace)
Sharing & Learning	-In Casa Jasmina ***we have learned something by sharing our space*** with Parametric Lace; we would like to open-source parametric techniques and fabricate similar furnishings with the tools of Maker culture. -I found ***our discussions to be among the most rewarding aspects of the stay***. From the IoT Meet-up on the rooftop to the espresso/prosecco-fueled kitchen table chats, we ***opened up a lot of juicy questions***	- Company culture and benefits are amazing. People Incentives to learn and improve your craft. -I think everybody wins ***with the in-residence program***. I'm looking forward to working side-by-side with the SparkFun team, and ***I think SparkFun benefits by learning about the creative projects from other makers***.	-"For me," says Jasen Wang, a Chaihuo member, "***it's about the people*** — [***having] a place to share***, a place to talk." -Hao have been back to China and start organizing a group of robot hobbyists to build a second prototype of DORA in awesome Chaihuo Makerspace in Shenzhen, China since the end of April. ***We meet up each Saturday night at Chaihuo Makerspace to share knowledge, skill and passion about building robots***. (Hao Zhang-Dorabot, 2013)
Improve creative output/ weaker group identification	***Casa Jasmina taps into local culture***, tradition and strengths, namely Torino's industrial design heritage as well as its location right at the epicenter of the open source hardware ecosystem, the place where Arduino was invented (and for a long time, built)... ***To draw from true diversity, it'd be great to build plenty of local Casa Jasminas around the globe***, each tapping into local cultures, assumptions and ways of life. - So the public of Turin just doesn't much mingle with Toolbox, Arduino Office, Fab Lab or Print Club. These four groups inside Via Egeo rarely visit each other, even, except for seminars, training lectures, show-and-tell meet-	***-Ideas are born everywhere - inside and outside our headquarters. Fifteen percent of the ideas for SparkFun Originals come from outside the building (which we then pay royalties on).*** But within the building, there is one staffer dedicated to fueling the new product pipeline. -I think ***diversity is one of the most important features of the open source movement,*** and creating spaces like the Hacker-in-Residence program is vital. ***You never know which new ideas can be sparked from such an awesome environment***. - Environment can be a lot like high school, with cliques and gossip and backstabbing. There's very little professional respect for anyone who's not an engineer or developer. Culture is cult-like and misogynistic. If you're a woman and/or in a non-engineering field, this place is very frustrating and draining. (anonymous employee review in Glassdoor)	-Chaihuo since early this year [2013] ***has moved to a new spot in the OCT Loft, which is the design neighborhood of Shenzhen. It's very artsy with a lot of designers***, a very very interesting place and you can hang out for the whole Sunday afternoon. We finally ***convinced the owner that we belong to the neighborhoo***d and they let us rent some space. -"**Chaihuo Makerspace provides tools and guidance to student makers who visit our base regularly," said a staff member surnamed Liu… For instance, younger children aged between 6 and 12 years old** can make products with a small package that contains all the materials, tools and instructions while older students can come to our center and learn about the more comprehensive coding process with guidance from adult makers,"

ups, and the occasional nice barbecue up on the roof.

They do have a clubhouse of sorts, ***though, which is "Casa Jasmina." Casa Jasmina changes the social atmosphere inside Via Egeo because it is presented as a "house" rather than as a "lab," "office," "club" or "toolbox." What's more, these distinctions of space are much more than verbal labels: people genuinely change how they behave. You can see that in their posture, tone of voice, how they move, sit, eat and even what topics they choose to talk about.***

Table 4.7. 5 (continued)

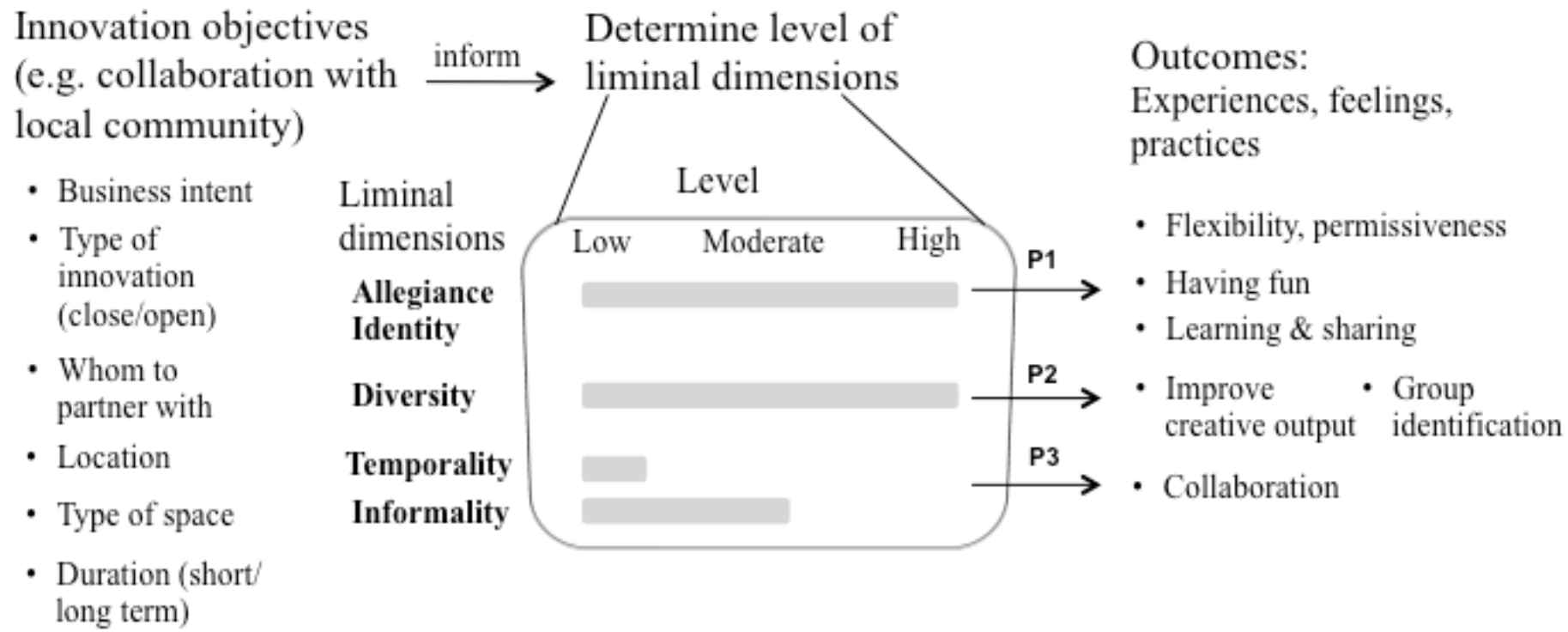
Experiences	Casa Jasmina	SparkFun HQ	Chaihuo makerspace
Flexibility/ autonomy	-The rules as a guest—and as a host—have not been written yet. The relationship is being negotiated, as is the space itself. Norms get to be re-imagined and invented. - The 'Casa' and its inhabitants are notedly welcoming to guests, and the hospitality we experienced this time was no exception. Art in modernism on the other hand had struggled with domestic life since its conception – most artwork is plainly unsuitable for normal household conditions. And this property it shares with digital technology… The art at Casa Jasmina is thus not so much about *art* but about *home*. The real art project is the whole Casa, with everything that has been going on inside it from the beginning.	-I'm a big fan of **"in-residence" programs** - hacker or otherwise. They ***allow a level of brainstorming and semi-agendaless thought process that can't usually happen in a day-to day-business,*** and can often lead in exciting directions. In the worst case, they are simply great promotion for a company showing an interest in a community, which isn't bad at all, and the best cases are impossible to imagine and limitless. (Resident, SparkFun website) -We were all grown up, and ***we could drink beer at work if we wanted to. And surprisingly, it helped! The flow of new ideas*** and great conversations was fantastic. So we decided in 2006 to get a kegerator. Our building-mates (medical device and drug manufacturers) thought us quite odd indeed. We decided it was important to put a few rules around the keg, so over a beer ***we collectively made some rules*** to make the office a place we all wanted to work. - I had no preconceived notions of what the work environment should be like. I made a place where I felt like I would want to work. ***The work culture here is pretty laid back***; there's certainly ***no dress code***. Also, over time people started asking if they could ***bring their dogs into work***. My response was, "Well I'm not really a dog person, but if it would make you happier and you can take care of your dogs, go ahead and bring them in." Then the skateboards showed up, then the ***loud music***. So now we have this wonderful culture of controlled chaos. It's crazy, but it makes for a pretty good work environment, and now we have just a bunch of friends working together	...the first hackerspace in Shenzhen, providing ***a platform that enables designers, DIY enthusiasts, inventors and makers to develop their ideas in a supportive environment***, attend workshops and share their experiences, while ***occasional visitors can have a go in using controllers and circuits*** to make all sorts of things. - Halo, which is building a heads-up display for cars, and Dorabot, which is developing a robotic arm for warehouse order fulfilment. In each case, the founders met each other at Chaihuo proper, ***initially using the space for their hobby before developing an idea that they thought had commercial potential***. After moving into Chaihuo VIP and setting up a company, they are now looking for venture capital funding. Rather than the Chaihuo to Chaihuo VIP graduation being a planned one, the space has popped up organically after the success of these two impromptu companies, none of whose founders particularly intended to start businesses.

Table 4.7. 5 (continued)

Experiences	Casa Jasmina	SparkFun HQ	Chaihuo makerspace
Having fun	-The relationship is being negotiated, as is the space itself. Norms get to be re-imagined and invented. ***That's fun***. -Smart things in the Casa Jasmina so far consist mostly of works of art, playing with concepts of *Calm Technology*. Some off-the-shelf smart tech has also found its way into the house. A Roomba, not connected at all, however in a way autonomous, and a Samsung Smart TV set. Right on the evening of the Casa's grand opening, Juventus Turin faced FC Barcelona in the Champions League's final, a game not to be missed by anybody in Turin, of course. But despite all the nerdy and geeky people around, we weren't able to get this Smart TV set. In the end, I plugged my Laptop into the Samsung set, degrading it into a totally dumb screen for the really smart and connected however totally 20th century device that my PC is.	-...working here is unusual, in the best of ways. Between the 30+ dogs present on any given day, the no-shoes-required dress code, and other eccentricities of SparkFun, ***the office is never dull***.' -There are a lot of really great people that work at SparkFun. What the company does is really cool. ***The building itself is quirky and fun***, and the employee discount is great for parts. (anonymous employee review in Glassdoor) -***We're always looking for more ways to make our office fun and strange***. One of our engineers, Mike, recently rigged up the elevator to play the Tardis noise. I wanted to do something similar, but, specifically, in my office. I don't often work with my door closed, but the majority of time when someone comes into my office, they give the door the ceremonial announcement rap to indicate their presence. I decided to have a little fun with that. Instead of the door making the standard boring door noise, I wanted my door to sound like the castle doorknockers from Young Frankenstein. (C.Taylor, 2012)	- I see Chaihuo as so different from any other hacker space **because it's in Shenzhen** and the people here are more focused on ***not only making some fun projects but also in turning them into real products***, to commercialize as a startup. - ***This was overall a relaxed and fun event, and a great social opportunity.*** Many of the attendees were industrial designers and product developers***. It's a place to make friends and connections.*** (Ray, Sep 2013)

Collaboration	-As the first guests in Casa Jasmina, we of course had to respect our hosts' wishes. ***We had to leave a contribution***. Bringing housewarming gifts. Being active, thoughtful participants. Making things to help other guests. The other kind of contribution we made was ***to help others participate in the space*****.** -"I hope to use Casa Jasmina's expertise in interaction design when doing this. Personally, *I see Casa Jasmina* ***as a fantastic opportunity to meet and connect with other designers and makers*** who aspire to create amazing functional, novel, sustainable and beautiful devices for the connected home of the future."	***- we were able to bring the SparkFun Autonomous Vehicle Competition (AVC) back to the SparkFun building***. AVC is SparkFun Electronics' flagship event, which pits robotics enthusiasts against each other in a no holds barred competition of speed and strength. The competition features an autonomous robot race and combat 'bot battles. ***Having AVC at [the] building is a great way for SparkFun Electronics to interact with the local community*** and encourage future engineers, roboticists and computer scientists. - we plan to use the classroom space in our building to host a variety of discussions, talks and presentations. It's the only large, air-conditioned space we can fit large groups of people in, so ***we want to take advantage of the space and create more opportunities for our community*** to show off their expertise. We have A/V equipment, projectors and other necessary equipment available for our speakers	-Chaihuo hosts less equipment, and encourages more on ***community building and collaboration***. Chaihuo members can easily turn to thousands of local suppliers to source professional and affordable services from laser cutting designs to customized circuit boards. - Eric Pan, the founder of SeeedStudio and ChaiHuo, has always been accommodating to me to host meetings there anytime, and the Startup Weekend committee group has been using the space for some nightly meetings. Cyril from China Accelerator will be down in Shenzhen after Chinese New Years as well, so this is a good group to cooperate with…(Mike Michelini, 2012)

Figure 4.7.1 Model crafting liminal spaces and propositions



5. CONCLUSION

This dissertation extends open source research beyond the software industry, towards the understanding of it in the production of tangible objects and its relationship with user communities (Raasch et al., 2009a; Raasch, Herstatt, Balka, & Abdelkafi, 2009b; Shah, 2005). The main dissertation's findings by chapter are presented in Table 5.2.1 and discussed below.

The first study (Chapter 2) attends the calls for research on firm-community interaction and its impact on the creation of markets (Dahlander, 2007; Fosfuri et al., 2011; O'Mahony and Lakhani, 2011). Through the longitudinal analysis of four cases I found three sets of firm-community interactions that influence the co-creation of the firm and market: 1) the identity enhancing interactions, both entrepreneurs and communities contribute to the unique identity of the firms, 2) interactions that fuels high levels of awareness and reputation and 3) knowledge sourcing. The findings support a systemic view of market creation and a co-creation approach with means for a systematic engagement with user communities (Fosfuri et al, 2011; Ramaswamy and Ozcan, 2014) by showing that firm-community interactions are mechanisms by which entrepreneurs enhance their ability to persuade audiences and define new paths or goals for their firms. The three sets of interactions contributed to the perception of value by market audiences, which helped with the acceptance of the market.

The second study (Chapter 3) centers on how the physicality and the weak appropriability conditions of open source influence the way firms appropriate value. The characteristics of firms and industries affect the selection of value capture mechanisms (James et al., 2013) and under such conditions a combination of appropriation strategies that change over time is necessary (Dahlander, 2005). Building upon OSS research, the study presents a portfolio of appropriation strategies that allow new entrants in OSHW to survive and grow. The findings uncover new appropriation mechanisms such as licenses and sources of revenue and suggest governance mechanisms employed to balance the inclusion of the community activities while firms control the final decisions (O'Mahony and Ferraro, 2007). Additionally, it contributes to support the view of the community as a complementary asset (Dahlander and Walling, 2006; Haefliger et al., 2010) by showing how and when firms with sponsored communities, incorporate community members in complementary activities (e.g. support, word of mouth) that help with the commercialization of products.

In the third study (Chapter 4) I explore first the link between physical spaces and firms strategic

and operational intentions regarding innovation (Moultrie et al., 2007) and second alternative spaces that support innovation (Lindtner et al., 2014). This study delineates four dimensions for crafting spaces and a social environment to induce innovative behavior: Temporality, informality, diversity and allegiance, which derive from liminal and interstitial conceptualization of spaces (Dale and Burrell, 2008; Furnari, 2014; Howard-Grenville et al., 2011). Additionally, it provides empirical support for theoretical assumptions on those types of spaces and the creation of favorable conditions for collaboration and creativity.

The dissertation provides an exploratory and empirical research on OSHW phenomenon from a management perspective and contributes to the incipient stream of research of open source for tangible objects (Balka et al., 2010; Lee et al., 2011; Raasch et al., 2009a; Vallance, 2001). The three empirical studies generated insights on topics relevant to management such as the creation and appropriation of value in new markets and firms' collaboration with communities (Dahlander, 2005; Dahlander and Magnusson, 2008; 2005; Khaire, 2014; O'Mahony and Lakhani, 2011; Shah, 2005). Further contributions are to the implementation of OI practices by linking external collaboration to the establishment of innovative spaces (Moultrie et al., 2007). By borrowing attributes of the liminality concept (Turner, 1967, 1987) I explain new ways of organizing, in which firms' interactions with people outside their boundaries foster innovation and help to source external knowledge (Dahlander and Gann, 2010; Waber et al., 2012). The dissertation's overall impact is shown in Appendix B.

Among the shortcomings and limitations of the dissertation is that all the qualitative analysis draws on cases that are successful firms in a single industry, which affects the generalization of the findings. This is a common limitation because of the lack of data for firms that fail, especially when studying a nascent market. A second limitation is the lack of performance measures. Although there are some indicators of firm performance these are not homogeneous among firms. Some of the firms do not publish financial performance or the number of units sold, others count the number of visitors or registered member to the companies' website as a proxy for community size or customer base, making the comparison of firms in terms of performance problematic. Finally, the empirical studies are based on qualitative techniques; the coding and the analysis were conducted by the author and then discussed with the academic advisors, for time reasons was not possible a validation with field experts. This process although consistent in the method, failed to provide other perspectives as diverse people might produce other interpretations.

5.1 Defining a research agenda for OSHW

Future research on OSHW may address management topics that can be classified in three overarching themes:

a) Emergence of firms, communities and markets. The extension of OSHW to other industries that traditionally have enforced knowledge protection mechanisms, e.g. Biotech, music, automotive, fashion, etc., brings contextual differences to consider and new research opportunities. In addition, linking community actions to organizational processes like the genesis of firms and markets helps to explain why one of the earliest steps of entrepreneurs often involves building user communities, but communities can also be the genesis of new forms in established industries (O'Mahony and Lakhani, 2011; West and Lakhani, 2008). For example, the 3D printing technology, developed in the 80's, was popularized to individual consumers in 2009-2010, thanks to the success of Makerbot (formerly open source from 2009 to 2012). Makerbot built on the RepRap project and its community and opened a new market for many startups offering open source 3D printers. This situation could be replicated to other industries, e.g. the electric vehicles; Tesla recently opened all its patents with that aim (Tesla, 2014). Further questions to address are:

- How do OSHW and their communities contribute to the popularization (emergence or re-emergence) of an industry?
- How is IP adapted to the different OSHW contexts?
- How do firms that transition from openness to closed source hardware maintain the relationship their communities?
- Why are firms non-fully compliant with the OSHW (e.g. Raspberry Pi) considered part of the market in the minds of the audiences?
- How does the growth of the firms or the communities affect firm-community relationships? What are the trade-offs for firms that have a larger, diverse user base?

b) Innovation spaces. Digitalization facilitated firms' collaboration with communities over Internet. However, there are implications for physical collaboration, from the new type of spaces in which firms and external communities interact to the way the interactions take place. The use of space as means to foster innovation is not necessarily linked to OSHW but can facilitate the building of a community at a local level with interesting new paths, for instance Genspace is a sort of genetics FabLab (Genspace, 2016). And there are new challenges for physical designs in modularity and task decomposition (Lakhani, Lifshitz-Assaf, & Tushman, 2012) and firms' approaches to OI. For instance, Seeed Studio did a kind of investment in the

community to provide a place for people's experimentation, i.e. a sponsored makerspace and when members' inventions require to be prototyped or produced in small scale, Seeed helps them with small batch production (SIDA, 2016) kind of front-shop-back-factory model. Another approach is Arduino and its living labs and officine, a combination of office and makerspace that produce innovations to commercialize. Thus, there are questions to be answered:

- In what ways alternative innovation spaces are helping OSHW firms to their sustainability?
- How do alternative spaces contribute the firms' effectiveness and efficiency on innovation? It is important to investigate measurements, e.g. increase quality and quantity of new ideas, improve speed, etc.
- To what extent differences in sponsorship of alternative spaces affect the building of the community and innovation outputs as compared to the ones with no corporate support or affiliation (e.g. non-profit)?
- How could firms design modularity for OSHW project for external collaboration carried out in physical spaces?

c) Social innovation. The social impact of OSHW on issues such as quality of life and well being is another area to explore. It was not discussed in the dissertation but it came in the data, some of the firms produced devices, sometimes with the help of the community that were sold or donated for a social cause such as an open source radiation sensor to help in the wake of the Japanese Tsunami earthquake (Seeed Studio and SparkFun) and the Tokyo Hackerspace has developed an Arduino-based geiger shield to build a radiation detector. The examples for disaster relief, the production of medical devices (Niezen, Eslambolchilar, Thimbleby, 2016) and outside electronics, initiatives for designing affordable, open source housing accessible to everyone such as the Open Building Institute (OBI), Paperhouses, Enviu, or Earth Dwellings (Pearce, 2016), suggest the following research questions:

- How do OSHW firms manage the paradox of generating financial returns for entrepreneurs and creating social returns for customers and users?
- How do OSHW firms and its global and diverse communities organize to support social innovation for challenges that local communities are experiencing? How does it differ from organizing for doing a usual commercial product?

While much work on OSHW remains to be done, the dissertation favorably attests to the theoretical and practical value of research on OSHW and its communities from a management perspective.

5.2 Tables

Table 5.2. 1 Dissertation's main findings

	Chapter 2 – Building user communities & the co-creation of a market	**Chapter 3 - On appropriability strategies for OSHW**	**Chapter 4 - Crafting physical spaces in open innovation environments**
Unit of Analysis	Firm-community interaction, Means and differentiation mechanisms	Firm's appropriability regime	Firm's physical spaces
Main finding	A repertoire of firm-community interactions (identity, reputation and knowledge sourcing) contributed to the co-creation of value that lead to the emergence of the market.	Open source tangible products influence the portfolio of appropriation mechanisms. New mechanisms for OSHW are licenses and sources of revenues, e.g. manufacturing services. In addition, firms' governance mechanisms to manage rather that own complementary assets.	Conceptualization of the implementation of firms' open innovation objectives with the help of physical spaces. Liminal dimensions (*allegiance, informality, diversity and temporality)* are mechanisms involved in the creation of spaces that facilitate the conditions for collaboration and creativity. They impact the perceived experiences of visitors and interactions happening in the space, which ultimately induce innovative behavior.
Secondary finding	New entrants exploit other attributes of community beyond product development, e.g. co-creation of an identity and co-develop a reputation that influence the chances of survival through the implementation of systematic practices and regular engagement with user communities	Access to community activities such as documentation, testing, marketing, etc. by sponsoring communities support the view of the community as complementary asset.	It provides empirical evidence to support theoretical assumptions that specific types of spaces (liminal/interstitial) create favorable conditions for creativity.

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APPENDIX A: ADDITIONAL MATERIAL

Table A.1 Communities' online data sources

	Forum link	Author	Notes	Date
Arduino	http://forum.arduino.cc/	Employees and users/moderator nominated by users	264,521 Members, March 2015 Most Online Ever: 4,125 (Feb 20, 2015, 03:37 pm)	New forum online (First post) Jul 21, 2005
	http://forum.arduino.cc/index.php?topic=54857.0		Moderators topic. Moderation Guidelines && Applications for Moderators	Mar 09, 2011, 11:00 pm
	http://forum.arduino.cc/index.php?topic=287775.0		Moderators topic	
	http://forum.arduino.cc/index.php?topic=231471.0	B@tto	Moderators topic. How to become a moderator?	Apr 07, 2014, 11:10 am
	http://forum.arduino.cc/index.php?topic=1596.0	Arduino community member	SparkFun overpriced	Jul 10, 2010
Beagleboard	http://beagleboard.org/Community/Forums	BeagleBoard forum use the Google forum tool	9908 members, March 2015	
		User initiated	How do I reach the moderator of this Google Group?	24/07/2012
		Founder initiated	Moderation temporarily disabled	03/04/2012

Table A.1. Communities' online data sources (continued)

	Forum link	Author	Notes	Date
			34136 members March 2015 Most users ever online was 430 on	by sparky latest post (new ideas section)
SparkFun	https://forum.SparkFun.com/	Employees and superusers	Thu Jan 07, 2010 10:51 am	May 29, 2003
	https://forum.SparkFun.com/viewtopic.php?f=5&t=4	sparky, site Admin	New product ideas	May 05, 2003
	https://forum.SparkFun.com/viewtopic.php?f=5&t=27089		SuperUser	Mar 08, 2011
	https://forum.SparkFun.com/viewtopic.php?f=16&t=35486	Frencil, site admin	Selling subsidiary BatchPCB	Apr 22, 2013
	https://forum.SparkFun.com/viewtopic.php?f=16&t=976	PJMonty	Demanding reply, offering help to write sw for free	Mar 27, 2005
			9037 Members Most users ever online was 144 on	
Seeed Technology Inc. (SeeedStudio)	http://www.seeedstudio.com/forum/	Forum with a reward system	Nov 06, 2013 8:22 pm	
	http://www.seeedstudio.com/forum/viewtopic.php?f=3&t=4382&p=16542&hilit=copyright#p16542	Initiated by user, moderator Jacket Chen	Sawers Studio is copying your website	Wed Mar 27, 2013
	http://www.seeedstudio.com/forum/viewtopic.php?f=3&t=5803		Reward system explained	Feb 09, 2015
	http://www.seeedstudio.com/forum/viewtopic.php?f=6&t=95&p=354&hilit=moderators#p354	Moderators from the users-base		Apr 14, 2009
	http://www.seeedstudio.com/forum/viewtopic.php?f=3&t=3288	Moderators from the users-base/Spam		May 17, 2012

Table A.1 Communities' online data sources (continued)

	Blog link	Author	Notes	Date	Comments
Arduino	http://blog.arduino.cc/	Founders & employees		August 10th, 2007	
	David Cuartielles (Spanish)		Cofounder blog		
	MAKE: Blog's Arduino archive		Collaborator blog		
	Tom Igoe's PComp Site		Cofounder blog		
	http://blog.arduino.cc/2013/07/10/send-in-the-clones/comment-page-1/	M. Banzi	founder about clones	July 10th, 2013	30 responses
	http://blog.arduino.cc/2012/01/	dcuartielles	Slow site performance due to infrastructure	January 16th, 2012	6 responses
Beagleboard	http://beagleboard.org/blog	Jason Kridner	109 entries		
SparkFun	https://www.SparkFun.com/news/300	Nathan Seidle	Desist letter to register the trademark	October 23, 2009	442 comments
	https://www.SparkFun.com/news/488	Nathan Seidle	About copycat the site	November 29, 2010	123 comments
	https://www.SparkFun.com/news/1575	Nathan Seidle	Recognizing mistakes	August 20, 2014	125 comments
	https://www.SparkFun.com/news/1428	Nathan Seidle	Legal controversies and getting response from the community	March 19, 2014	327 comments
Seeed Technology Inc. (SeeedStudio)	http://www.seeedstudio.com/blog/	Admin		August 22, 2008	
	http://blog.atmel.com/2014/03/03/eric-pan-from-seeed-studio-to-haxlr8r/	Aharon Etengoff		March 3, 2014	
	http://www.hackthings.com/2013/04/			April 30, 2013	

Table A.2 Word frequency by venture (Chapter 2)

Arduino

Year	2006		2007		2008		2009		2010	
#Articles	7		7		9		41		40	
	Word	Count	Word	Count	Word	Count	Word	Count	Word	Count
	Arte	33	Arduino	14	Arduino	67	Arduino	175	Arduino	113
	Cuartielles	21	Source	14	hardware	49	Source	147	Design	99
	Festival	15	Hardware	13	Open	47	Open	146	Open	87
	Arduino	15	Open	13	software	44	Hardware	111	Electronics	91
	Proyecto	18	Arte	12	Source	41	Software	103	Software	72
	Electronica	23	Electronic	13	computer	41	Design	83	Source	65
	Ars	14	Digital	9	electronics	31	Projects	79	Technology	63
	digital	12	Libre	8	System	28	Computer	92	Community	54
	Experimental	8	Tecnologia	8	Hacker	17	Make	68	Hardware	53
	Tecnologias	15	Web	8	platform	17	Technology	60	Computer	46
	Vanguardia	8	Cuartielles	7	Design	16	Board	59	Make	46
	Simplicidad	9	Device	7	Devices	16	Hack	55	Board	54
	Plataforma	5	Document	7	simple	16	Engineering	41	Components	39
	Comunidad	4	Igoe	7	boards	15	Students	41	Engineers	39
	massimo banzi	4	Java	7	physical	15	Development	36	Development	35
	Mellis	4	Proyecto	6	development	14	Project	36	Platform	33
	Hardware	2	Visual	6	prototyping	14	Digital	35	Arte	32
	Software	2	development	5	components	13	Developers	30	Projects	72
	open source	1	information	5	technology	13	Electronics	52	Programming	27
	Components	1	Physical	5	Board	12	Tinkering	74	Maker	26
	Computing	5	Community	6	devices	12	Device	27	Device	25
	Board	1	Make	4	community	11	Physical	27	Movement	24
			Platform	4	Easy	11	System	26	Processing	24

Project	4	Make	11	Platform	24	Hacks	62
Software	4	microcontroller	11	Boards	22	Libre	23
Computer	8	hacking	10	microcontrollers	34	Simple	22
microcontroller	4	circuit	8	Community	17	Embedded	21
		massimo banzi	5	Banzi	17	System	21
				Designers	17	Microcontroller	14

Table A.2 Word frequency by venture (continued)

SparkFun

	2005		2006		2007		2008		2009	
#Articles	1		2		2		8		9	
	Word	Count	Word	Count	Word	Count	Word	Count	Word	Count
	Spark	4	Computer	3	devices	20	Computer	52	arduino	45
	Board	1	Laptop	2	design	14	User	37	open	35
	Digital	1	Manufactured	2	open	10	System	21	source	34
	electronics	1	Spark	2	nathan	9	Technology	14	computer	32
	SparkFun	1	SparkFun	2	source	8	Devices	25	software	22
	Systems	1	Electronics	2	hardware	7	Prototype	16	students	21
	technology	1	Device	1	electronics	6	Electronic	15	projects	30
					project	6	SparkFun	9	electronics	25
					SparkFun	6	Board	8	SparkFun	17
					developer	7	Hardware	7	hardware	16
					spark	5	Simple	7	design	14
					production	3	Components	6	microcontrollers	21
					project	3	Development	5	technology	14
					digital	2	Embedded	5	device	11
					engineers	2	Open	4	development	10
					prototype	2	Digital	3	tinkerers	19
					firmware	2	Laptop	3	seidle	8
					arduino	1	Microcontroller	3	boards	7
							Developers	2	designers	7
									engineer	7
									system	7
									banzi	6
									hackerspace	12
									production	6
									manufacturers	9

hobbyists	7
cuartielles	2
developer	2
entrepreneurs	2
makers	2

BeagleBoard

	2008		2009		2010		2011		2012	
#Articles	5		14		17		22		22	
	Word	Count	Word	Count	Word	Count	Word	Count	Word	Count
	Board	62	Development	98	Beagleboard	88	Open	133	Embedded	160
	Beagle	45	Design	93	Board	64	Source	121	Linux	128
	Embedded	43	Technology	99	development	63	Development	104	Open	125
	Development	30	Source	71	embedded	52	Linux	99	Source	120
	System	40	Open	71	Digi	44	Beagleboard	93	Beaglebone	99
	Digi	20	Software	60	Design	37	Embedded	80	Development	97
	Design	19	Beagleboard	57	Open	37	Community	86	Raspberry	94
	Platform	13	Hardware	57	Systems	58	Board	96	Beagleboard	90
	Technology	13	Texas	52	Boards	35	Design	89	Cape	115
	Open	14	Board	54	community	27	Arduino	70	Board	156
	Developers	11	Embedded	45	Devices	41	Hardware	68	Hardware	73
	Devices	11	Developers	42	Texas	27	Electronics	84	Software	71
	Community	14	Platform	42	Linux	26	Devices	79	Design	60
	Semiconductor	10	Community	31	Computer	38	Platform	75	Community	60
	Texas	10	Devices	30	Software	24	Software	58	Project	84
	Beagleboard	9	Systems	55	Developers	23	Systems	100	Computer	65
	Source	9	Linux	25	Hardware	23	Technology	73	Electronics	61
	Microcontrollers	4	Electronics	22	Users	22	Computer	41	System	90
	Projects	4	Components	14	Platform	28	Org	40	Developers	51

Microelectronics	3	Beagle	11	Org	21	Developers	36	Arduino	48
Forums	2	Projects	11	technology	18	Beaglebone	35	Devices	45
Linux	8	Standard	11	electronic	14	Engineers	33	Platform	62
Hardware	5	Designers	10	Standard	19	Microprocessors	29	Processor	64
Makers	1	Engineers	10	semiconductor	9	Components	18	Students	35
Org	16	Students	4	engineers	8	Projects	17	Engineers	35
Hobbyists	2	Org	20	Beagle	7	Standard	12	Texas	26
		Laptop	5	microcontroller	11	Hobbyists	11	Hobbyists	18
		Hobbyists	3	prototype	6	Maker	11	Chip	13
				microprocessors	6	Microcontrollers	18	microcontroller	18
				beagletouch	5	Fabrication	40	Makers	8
				Students	5	Semiconductor	7	semiconductor	8
				Forums	2	Students	6	Designers	6
				Makers	3	Beagle	4	Beagle	5

Table A.2. Word frequency by venture (continued)

Seeed Studio

	2010		2011		2012		2013	
#Articles	2		2		3		7	
	Word	Count	Word	Count	Word	Count	Word	Count
	Seeed	24	Embedded	10	Design	11	Open	69
	Open	15	System	7	development	9	Hardware	40
	Manufacture	7	Design	4	System	9	Maker	51
	Community	6	Engineers	4	Seeed	7	Seeed	27
	Eric	6	Hardware	4	Product	4	Source	27
	Product	9	Computer	3	prototyping	6	Eric	23
	Service	6	Controller	3	Digital	3	Electronics	21
	Source	5	Technology	3	electronics	5	Arduino	18
	Design	6	Seeed	2	Hardware	3	Design	15
	Hackerspace	5	Source	2	microcontroller	3	Community	13
	Platform	3	Standards	2	Source	3	Technology	13
	Project	3	Development	2	Arduino	3	Movement	12
	Prototype	3	Device	1	Forums	2	Manufacturing	11
	Share	3	Electronics	1	Engineers	3	Development	10
	Designers	2	Hobbyist	1	Computer	3	Entrepreneurs	10
	Ecosystem	2	Maker	1	Designer	2	Projects	10
	Electronics	2	Projects	1	Device	2	Components	8
	Seeedstudio	1	Seeedstudio	1	Component	1	Hack	11
	Movement	1	Semiconductor	1	Counterfeit	2	Kickstarter	6
			Manufacturing	1	Platform	1	Computer	5

Figure A.1 Popularity comparison. Source: Google trends

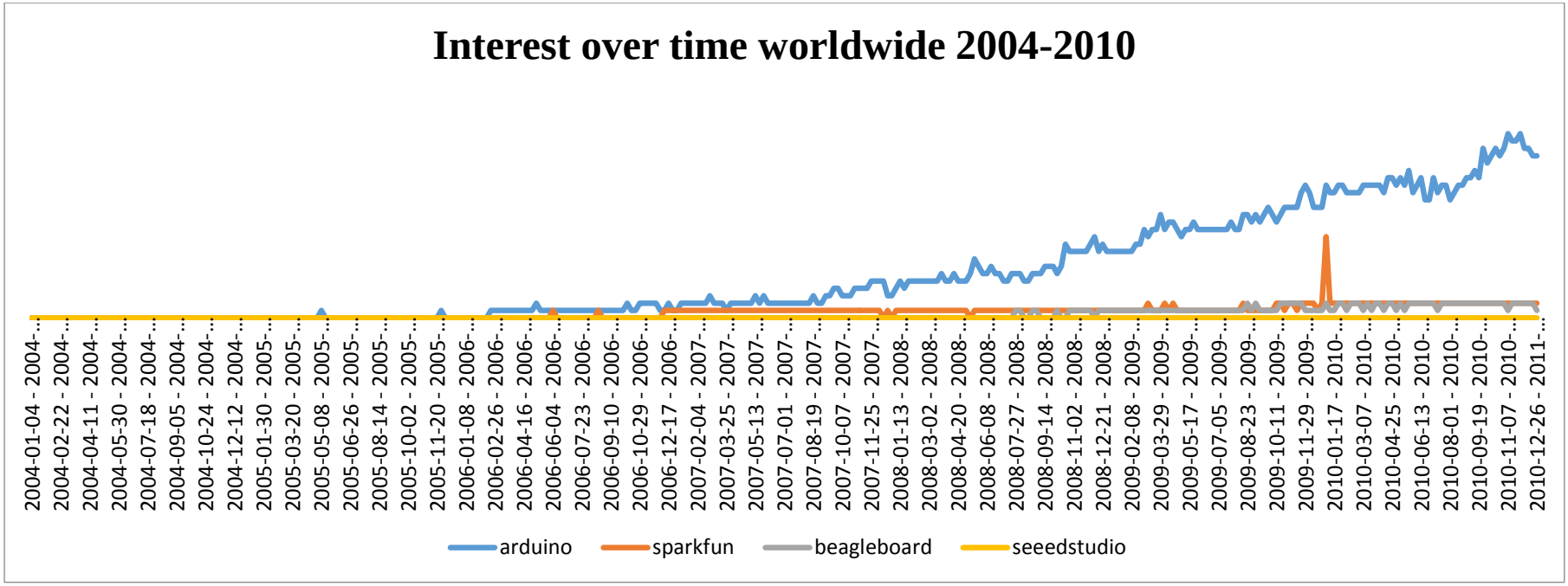

Table A.3 Differentiation Strategies

Differentiation mechanisms	Authors	Description
Reference Group	Chen & O'Mahony, 2009	What practices to avoid contributing to organizational novelty, proprietary and mass production vs. free & small scale
Symbolic Management	Granqvist et al., 2013	Use industry labels in the name of the firm, claiming affiliation or disassociation
Vocabulary-recombination; lexical variety	Grodal et al., 2015	e.g. ebook (electronic book), software as a service (SaaS)
Adopting templates	Santos & Eisenhardt, 2009	Use of cognitive models from other areas, together with values, practices and vocabulary
Providing leadership signals	Santos & Eisenhardt, 2009	Concrete actions that convey superior expertise and/or power (e.g establishing standards, litigation threats, proclaiming big achievements, endorsement of high profile figures)
Dissemination of stories	Santos & Eisenhardt, 2009	Spreading of symbolic narratives about the company and/or market (fictitious or real)

Table A.4 Mechanisms quotes (Chapter 2)

	Firm (Adopt templates)	Community-values
Arduino	Small, inexpensive, open-source I/O board based on the Wiring IDE. It is used to deploy designs developed with Wiring. It's useful when you want to make multiple objects and don't want to give away your precious Wiring board	"The product is well supported, open to new uses and variations, the community is not hindered by corporate greed or desire to control ideas… The number of people who have been able to do things with it without the knowledge or support." (easy to use). Dangerous prototypes\-Marc, September 3, 2009 at 2:55 pm
BeagleBoard	The Beagle Board is a low-cost, fanless embedded development board that unleashes laptop-like performance without the bulk, expense or noise of typical desktop machines (http://beagleboard.org). The USB-powered Beagle Board is smaller than a drink coaster and is based on a Texas Instruments (TI) OMAP35x applications processor featuring the ARM(R) Cortex(TM)-A8 core (http://www.ti.com/omap35x).	"TI really keeps beagleboard.org separate from corporate TI," said Kridner. "We got a tremendous amount of guidance from the community about developing the product."
Sparkfun	Spark Fun sells printed circuit boards, microcontrollers and other small electronic parts that make up the tiny computer chips found in almost any electronic device... As the company has grown with customer loyalty, the Web site has moved beyond just a retail hub – it's become a forum for electronic enthusiasts around the world. Spark Fun employees freely exchange information with their customers, which benefits both sides, Seidle said. He has no problem posting valuable company schematics and documentation online for free. And Seidle doesn't mind his employees experimenting with company product lines.	The Bus Pirate developers don't get a cut of the SparkFun Bus Pirate sales, but we're proud our hardware is featured at another site. SparkFun is a great company with a reputation for working with open source hardware. Posted on Tuesday, December 22nd, 2009 in Bus Pirate by Ian (Dangerous Prototypes) Ian says: December 27, 2013 at 3:58 am We didn't get anything from them at first, but once Nate realized we were selling them too he insisted on paying a royalty. This post is probably before that happened.
SeeedStudio	This is the first open source board from our studio, we are proud to name it Seeeduino. However, it is never going to be built without the great community.	There are already many decentralized communities, Seeed would like to connect to them and collaborate as much as possible.

Table A.4 Mechanisms quotes (continued)

	Firm (Story telling)	User Community
Arduino	"We did 200 copies, and my school bought 50," Banzi says. "We had no idea how we'd sell the other 150. We didn't think we would." But word spread to hobbyists worldwide, and a few months later there were orders for hundreds more Arduinos. Turns out there was a market for this thing.	Word of Arduino quickly spread online, with no marketing or advertising. Early on, it attracted the attention of Tom Igoe, a professor of physical computing at the Interactive Telecommunications Program at New York University and today a member of the core Arduino team. Igoe had been teaching courses to nontechnical students using the BASIC Stamp but was impressed by Arduino's features.
BeagleBoard	We spoke with TI open platform architect Jason Kridner, who explained that the function of the Beagle Board is to empower enthusiasts and enable them to innovate in the hardware space. He says that a vibrant community has already sprung up around the product and is exploring applications ranging from homebrew media centers to wearable computing.	In the beginning, overzealous semiconductor vendor overlords commanded that every developer beg on their hands and knees to use the latest technology on the latest development kits. The overlords demanded outrageous sums of money and refused to offer any help. The earth became a desolate wasteland of overpriced and poorly supported development kits. The masses suffered as the privileged look from upon their thrones. Then, two engineers — we'll call them Jason and Gerald — came upon the idea of creating a low-priced open-source platform that everyone could use and support. Word of this idea quickly traveled to the overlords and, needless to say, they were not pleased. They demanded the heads of these engineers. Jason and Gerald were able to escape and found refuge in a land called Texas.

Table A.4 Mechanisms quotes (continued)

	Firm (Story telling)	User Community
Sparkfun	In the beginning of 2003, whenever I first started the company – we were in bedrooms and basements for the first three years.	However, the most impressive thing in this story is not what Sparkfun has achieved but how. There are two factors to this tale that are highly rare in business culture. The first is that Seidle never asked for a loan or any form of investment, i.e. he spent only the money he had earned before, and therefore he was creating profits from day one. The second factor that sets him apart from the herd is that the company is 100% open source. In fact today it is considered to be the largest open source hardware manufacturer in the world.
SeeedStudio	Seeed Studio, exemplifies a new breed of Chinese entrepreneur. He quit his tech-industry job in 2008 to start making hardware with a friend, based in his apartment (the urban Chinese equivalent of a garage). Now his company employs more than 100 people, and the unassuming Mr Pan is a rock-star among young Chinese geeks. Even so, he is quick to admit that not all Seeed Studio products are hits, and humble about the challenge of surviving as a business in an open-source world, where copying good ideas is not merely allowed but encouraged. Yet he is also bullish about the future: his firm is expanding its range of kit to include wearable electronics and new kinds of sensors	We headed to Shenzhen on Sunday to meet Eric and see Seeed Studio first hand. They are on the forefront of the open hardware movement (or indie hardware, artisanal hardware or whatever you might want to call it.) From their humble beginnings hacking things in a shared apartment in 2008, Eric has grown Seeed Studio into a company of over 100 people and built a platform for the advancement of open hardware development.

Table A.4 Mechanisms quotes (continued)

	Firm (Signal leadership)	User Community
Arduino	Banzi scoops up one of the boards and points to the tiny map of Italy emblazoned on it. "See? Italian manufacturing quality!" he says, laughing. "That's why everyone likes us!" Indeed, 50,000 Arduino units have been sold worldwide since mass production began two years ago. Those are small numbers by Intel standards but large for a startup outfit in a highly specialized market. What's really remarkable, though, is Arduino's business model: The team has created a company based on giving everything away. On its Web site, it posts all its trade secrets for anyone to take—all the schematics, design files, and software for the Arduino board. Download them and you can manufacture an Arduino yourself; there are no patents.	"Most design engineers say that Arduino has become popular due to simplicity of use that the platform offers. But this alone can't be the reason behind it," feels Jadhao. He adds, "The Arduino community has maintained and popularised the platform properly." "Arduino forums are an excellent means of communication amongst the community that not only help people but are also a rich source of new ideas and thoughts to build better and more advanced hardware and software for the future," says Ram. "In addition, many 'how to' guides and project ideas are available in the public domain. The design ideas and users' experiences are also shared in the community, which makes it easy even for beginners to work on the platform," informs Jadhao
BeagleBoard	BeagleBoard, which is a singleboard computer, is fast and powerful as it comes packed with a DM3730CBP 1GHz processor (commonly used in most smartphones), five USB 2.0 ports 512 MB of memory and on-board ethernet.	"A lot of people complain that Arduino is not powerful enough and if you want something that's more technical and intensive it is just not good enough," he says. "So BeagleBoard can be a very interesting alternative."

Table A.4 Mechanisms quotes (continued)

	Firm (Signal leadership)	User Community
Sparkfun	During winter break from the University of Colorado at Boulder, Seidle maxed out his credit card and built an online store, SparkFun Electronics. Orders rolled in. When shoppers called with delivery questions, Seidle offered to consult his shipping department. "Really, it was me sitting in my bedroom," he laughs. Six years and 47 employees later, Seidle has plenty more company. And SparkFun's annual revenue jumped from $846,881 in 2005 to $4 million in 2007 to nearly $7 million in 2008.	Anderson said he considers SparkFun a leader in the emerging open-source hardware movement not only because of the Boulder company's community-based retail site but also its offering of tutorials, classes and the annual Autonomous Vehicle Competition.
SeeedStudio	Seeed Studio was founded 3 years ago in Shenzhen to explore combining open source hardware and the electronics supply chain in Shenzhen. Today, Seeed Studio employes over 30 engineers and support staffs with over USD$1 million in annual revenue mainly from US, Europe and Japanese customers which are 98% of its business. Seeed does not yet focus on Chinese market as Eric points out that the tinkers/makers community in China has not yet matured enough for Seeed	As the success of Arduino has demonstrated, open-source hardware is ideal for quick prototyping and small-scale production runs of digital devices. But Seeed goes one step further, supporting a whole ecosystem of open-source production. People pitch ideas on its website, and if they garner enough community support, Seeed will manufacture them. More than 70,000 people are participating on its site, and over 130 projects were crowdsourced this way in 2012. Those numbers are expected to more than double in 2013.

Table A.4 Mechanisms quotes (continued)

	Firm (Emotional Appeal)	User Community
Arduino	Send in the clones. We believe firmly in open source hardware and we have always systematically released any hardware design and the software needed to reproduce our products. We think this advances the whole community and provides a platform for shared innovation where the advantages are more than the drawbacks, but we also think that Trademark violations are like identity theft: the same way each one of us wants to have the right to own their name we believe we have the right to decide whoever gets to be called Arduino	Keep up the great work guys, I will certainly only ever buy Official Arduino Boards with the only exceptions of the honest makers who are upfront about their product being derived from an official board and giving full credit of the main design to Arduino TM. There is currently one in the works who have added to the design & expanded on-board functionality by creating a Derivative of a Due for example with a Wifi, Micro SD card slot and RF radio built in on board.
BeagleBoard	The BeagleBone is more open source than the Raspberry Pi, claimed Kridner. "With the Pi, you cannot do anything you want with your design," he said. "You are not completely free to customize it or alter it." With the BeagleBone Black's lower price, Kridner expects developers will be more likely to compare the board with the Pi -- and like what they see. "At $45, you can put these boards in your projects and forget about them," said Kridner. "We're the ones that changed the market, and we continue to engage with the community. I don't think there's really a whole lot of room for too many other open source boards."	Because unlike the RPi, it's open hardware. Traditionally, all schematics from the BeagleBoard org have been available, and also, I've confirmed that the datasheet for the TI AM3358 is readily available – it took me 10 seconds to find it. TI is usually VERY good about providing hardware documentation. The BCM2835 in the Pi – Basically good luck getting the datasheet unless you're a megacorporation or an ex-employee like Eben of the RPi project is.

Table A.4 Mechanisms quotes (continued)

	Firm (Emotional Appeal)	User Community
Sparkfun	SparkFun is all about open. Whether sharing the pcb design files for our products or posting pictures from the office on flickr, we're pretty open about what it's like to work here. Today we'd like to share with you a cease and desist letter we received from SPARC International. We care deeply for what we are trying to create at SparkFun. We don't want anyone to be confused, but we feel badgered, beat-up, and picked on by a much larger company. We would really appreciate your support and comments on this matter. Please post any comments below. Feel free to contact sparcinfo@sparc.org with your thoughts. CC in spark@sparkfun.com! We'd love to hear your thoughts as well.	This is almost as bad as Apple trying to sue everybody with a lower-case i at the beginning of their name… Just total BS. I agree with Nick Nunns, Rock Art Brewery is a small business & they fought off Monster. Monster is also trying to Cease & Desist a behind-the-scenes photo of an actor in a horror film (dressed as a ghoul) holding a can of their beverage… Or even the whole Ralph Lauren Photoshop-FAIL ad & wired… You're not doing anything wrong, keep up the good work. If Sparc & SparkFun are confusingly similar, I think you've got bigger problems to worry about, like brain damage or poor eyesight,
SeeedStudio	We got inquires from Shigeru in Tokyo about Geiger Mueller Tube, as the nuclear accident in FUKUSHIMA is escalating. Can open hardware community do something to help in this? Seeed Studio is now sourcing sensors, then assemble quick measurement tools, ship as many/fast as possible to Japan. All creations will be open source and donated, thank you for helping out! Since we have no previous experience with such device, your help is needed!	folks over at Seeed Studio, purveyors of various how-to parts, are trying to do some serious good in the world using their hardware-hacker mentality. On their blog, the company has put out an open call for developers and hobbyists to collaborate on an open-source radiation detector that could help the residents of Fukushima Prefecture in Japan deal with the ongoing nuclear accident.

APPENDIX B: ACADEMIC PAPER PRESENTATIONS

Chapter 2: Building user communities and the co-creation of a market

2016 **76th Annual Meeting of the Academy of Management** Anaheim, USA.

Chapter 3: On appropriability strategies for Open Source Hardware

2015 **75th Annual Meeting of the Academy of Management,** Vancouver, BC, Canada.

2015 **31st EGOS Colloquium**, Athens, Greece.

Chapter 4: Crafting physical spaces in open innovation environments

2015 The importance of spaces in open source innovation. **APROS-EGOS,** Sydney, Australia.

2016 **15th International Business and Economy Conference**. Nurtingen, Germany.

2016 **Collaborative Spaces Workshop**, Cass Business School, London, United Kingdom.

2016 **76th Annual Meeting of the Academy of Management**, Anaheim, USA.